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SOME NOTES ON THE CORRECTION AND TESTING OF PARABOLIC MIRRORS.

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FOR POPULAR ASTRNOMY.

Some time ago my attention was called to the apparent confusion of ideas on the part of different opticians regarding the application of the Foucault method to the testing of the figure of a parabolic mirror at the center of curvature by determining what is commonly termed the "longitudinal aberration" of the figured surface at this point.

A perusal of the various papers that have been written by Draper, Calver, Wassell, Vital, Brashear and others on this subject seems, to show that the cause of this confusion is two-fold; 1st, in a lack of agreement as to the definition and the numerical amount of the aberration due to a true parabolic mirror when an image from the same is formed at the center of curvature, and 2d, in differences in the manner in which this amount is actually measured.

Draper, in his celebrated memoir* makes the following statement: "The longitudinal aberration of a mirror of small angular opening is—equal to the square of half the aperture divided by eight times the principal focal length.—If a mirror which can converge parallel rays falling on all its parts to one focus be examined at the center of curvature, it gives there an *amount of longitudinal aberration equal to twice the preceding.*" This statement has frequently been called in question. Thus Wassell says†: "The rule I use is, I believe, different to Dr. Draper's.—It is as follows: Divide the square of the semi-diameter—by double the focal length.—I judged from the arguments for this rule and for Dr. Draper's that Dr. Draper was mistaken." Vital takes a similar position in regard to Dr. Draper and gives as his formula for the longitudinal aberration the following

$$m = \frac{y^2}{2F} + \frac{y^4}{16F^3}\ddagger$$

* Construction of a Silvered Glass Telescope. Smithsonian Cont. to Knowledge, No. 180, p.

† *Eng. Mechanic*, Vol. 35 pp. 128, also pp. 238.

‡ *Eng. Mechanic*, Vol. 35, pp. 351, 402.

where y is the semi-aperture of the mirror and F its focal length. A similar formula is given by W. H. G.* Professor Hastings, in a letter written to Mr. Brashear and subsequently published in the *Eng. Mechanic* by Vital, gives the aberration of a parabolic mirror at the center of curvature as†

$$Cr = \frac{y^2}{16F}$$

Mr. Brashear himself states that his rule has been to make the longitudinal aberration equal to the square of the semi-aperture divided by four times the focal length.

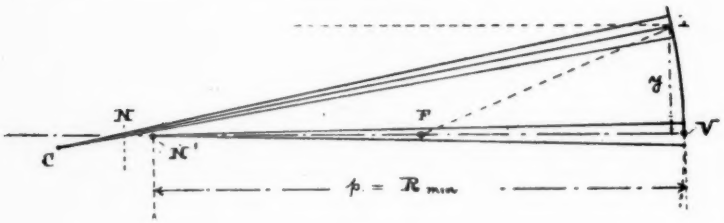


FIG. 1.

Before commenting in detail on these different results it will be instructive to consider briefly some of the geometrical properties of a parabola developed by the methods of Analytical Geometry and Calculus. The quantities with which we have to deal in the investigation of the present subject are: 1ts, the radius of curvature, PC, of any element of surface P on the parabolic curve, 2d the length of the normal PN from the center of this element to the intersection on the axis $V\,F\,N$, and 3d the distance VN from this point of intersection N to the vertex of the curve V.

The general expressions for (1), (2) and (3) in the case of any curve are

for (1)

$$R = \frac{\left[1 + \left(\frac{dy}{dx}\right)^2\right]^{3/2}}{\frac{d^2y}{dx^2}} \qquad (1)$$

* *Eng. Mechanics*, p. 351.

† *Ibid*, p. 351. There must be a typographical error in this result.

for (2)

$$PN = y\sqrt{1 + \left(\frac{dy}{dx}\right)^2} \tag{2}$$

for (3)

$$VN = x + y\frac{dy}{dx} \tag{3}$$

In the case of the parabola referred to the origin V as vertex we have

$$y^2 = 2px. \tag{4}$$

Hence by differentiation and substitution in the above we obtain at once for any point y on the curve

$$\left.\begin{aligned} R = \text{radius of curvature} &= \frac{(p^2 + y^2)^{3/2}}{p^2} \\ &= p + \frac{3y^2}{2p} + \frac{3y^4}{8p^3} + \ldots\ldots \end{aligned}\right\} \tag{5}$$

$$\left.\begin{aligned} PN = \text{length of normal} &= \sqrt{p^2 + y^2} \\ &= p + \frac{1}{2}\frac{y^2}{p} - \frac{1}{8}\frac{y^4}{p^3} + \ldots\ldots \end{aligned}\right\} \tag{6}$$

VN = distance from V to intersection of normal with axis

$$= p + \frac{1}{2}\frac{y^2}{p}. \tag{7}$$

When $y = 0$, (*i. e.* at the vertex), $R = p$ ... that is, the radius of curvature at the vertex of the parabola is p, or twice the principal focal length F of the curve for parallel rays. When y is small compared with F, that is when the angular aperture of the mirror is small, we may neglect all terms of the development beyond the third in (5) and (6), and substituting for p its value $2F$, we have for any point y on the mirror the following relations:

$$R = 2F + \frac{3y^2}{4F} + \frac{3y^4}{64F^3} \tag{8}$$

$$PN = 2F + \frac{y^2}{4F} - \frac{y^4}{64F^3} \tag{9}$$

$$VN = 2F + \frac{y^2}{4F} \tag{10}$$

A comparison of these three quantities and the distances which they represent shows at once the principal cause of the above differences between previous writers.

(1). Considering first the radii of curvature of the different parts of the parabolic surface we have for the maximum and minimum values of R

$$\text{At the center } R_{\min} = VN' = 2F$$

$$\text{At the edge } \quad R_{\max} = PC = 2F + 3\left(\frac{4^2}{4F} + \frac{y^4}{64F}\right) \quad (11)$$

Since light radiating from the center of curvatnre of any surface is returned by that surface to a focus at the same point, it follows that the difference, $R_{\max} - R_{\min}$, represents the maximum variation in the principal conjugate foci of different portions of a parabolic surface; *i. e.*, if we test the figure of a parabolic mirror by using a collimating eyepiece or, what amounts to the same thing, an eyepiece E and radiant point R which move together as in Fig. 2, we shall find that the difference in focus between a small portion of the surface at the center V and at the edge P is equal to three times the square of the semi-angular aperture divided by four times the focal length. (Neglecting powers of y/F higher than the second).

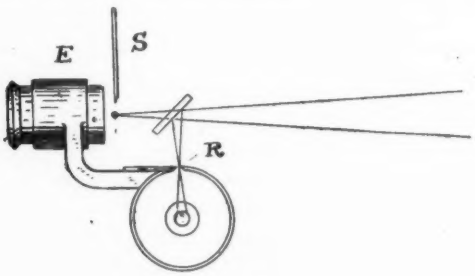


FIG. 2.

This is a quantity three times as large as that given by Draper and one and one-half times as large as that given by Wassell and others for the longitudinal aberration at the center of curvature. In testing a parabolic surface, however, opticians do not generally test individual elements of the surface but indlvidual *zones*, *i. e.*, the light from a given radiant test point R is reflected and examined simultaneously from two diametrically opposite points of a zone $A\ A'$, as in Figs. 3 and 4. In this case the conditions of test become entirely different, and the difference between the apparent foci of the outer and inner zones depend on several conditions which need to be carefully examined and differentiated.

It will be shown below that within quite wide limits the exact position of the radiant point is without effect on the measured differences in question. Therefore suppose it for simplicity to be placed at N, the point of intersection of the normals to the points $A\ A'$. Then the rays of light from N falling on the elements $A\ A'$ will be reflected back on their own path and cross at the starting point. If the elements $A\ A'$ are infinitely narrow there will be a sharp image of N formed at the point of intersection. In this case the variation in position of the focal point N for different pairs of elements is the variation in the value of VN as given by (10).

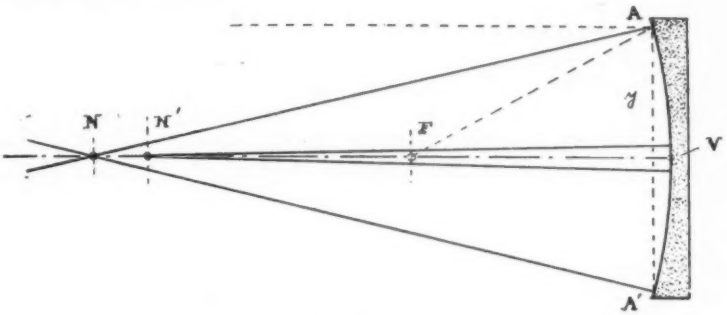


FIG. 3.

We have

$$VN_{max} = 2F + \frac{y^2}{4F} \cdots\cdots$$

$$VN'_{min} = 2F = R\ [\text{for } y = 0]$$

$$VN_{max} - NN'_{min} = \frac{y^2}{4F} \qquad (12)$$

which is the quantity given by Draper as the longitudinal aberration of a parabola at the center of curvature. Under the above conditions therefore, Draper's value for this quantity is correct and his succeeding critics are in error.

Under actual conditions of test, however, there will usually be a small difference between the above theoretical value and the actual quantity measured, even when the surface measured is a perfect parabola of revolution. The reason for this is that the point N of intersection of the normals is not the true focal point of the rays from either of the elements A or A' independently. For a radiant point at N the focus of the rays reflected

from the element A is at O, for the rays from A' at O' (Fig. 4). These two points are at a distance behind N equal to twice the difference between R and PN.

From (8) and (9) we find

$$R - PN = \frac{y^2}{2F} + \frac{y^4}{16F}$$

Hence the distance (13)

$$ON = O'N = \frac{y^2}{F} + \frac{y^4}{8F}$$

The actual width of the beam of rays AO and $A'O'$ at N, the point of intersection, will depend on the width of the elements A and A'. Let θ be the semi-angular aperture of the mirror—and let the width of the element A be $w = ny$, where n is of course a small proper fraction.

Then we have for the transverse width of beam at $N \cong cc'$

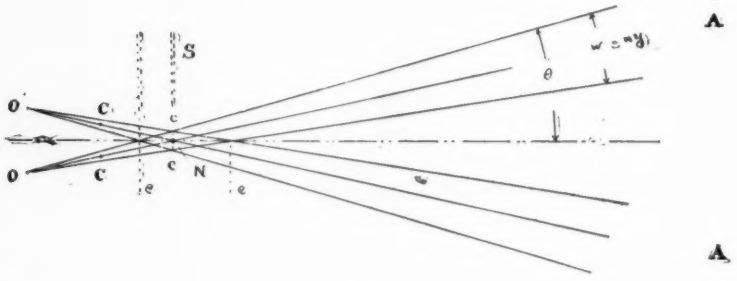


FIG. 4.

$$cc' \cong ON\frac{w}{2F} = \frac{wy^2}{2F^2} = 2w\theta^2 \qquad (14)$$

The resultant confusion of focus is represented by the distance ee' which is

$$ee' \cong cc'\ 2\frac{F}{y} = 2w\theta = w\frac{y}{F} = 4n \cdot \frac{y^2}{4F}$$

The *possible* ranges of focus on either side of the point N is one half the above; that is, the possible difference between the measured and the theoretical aberration of a true parabolic surface, is the theoretical value multiplied by twice the ratio between the width of the test zones and the semi-width of the mirror. If this

ratio is 1/10, the uncertainty in the measurement of the aberration may amount to as much as 20 per cent.

This uncertainty arises, as can be readily seen, from the question as to what criterion we shall adopt in determining the focal point of the intersecting rays. If an eyepiece is used, the point naturally chosen by most observers is the point N where the cross section of the two intersecting pencils is least. This point has been called, for this reason, the "position of the center of least confusion," and if it could be sharply defined it would afford us a means of making a measurement which would correspond exactly with the theory. The cones, however, intersect at such a a small angle that the change in the cross section of the resultant beam, and consequent change in the sharpness and smallness of the image of the radiant point, is so gradual that the setting of the eyepiece is indefinite and uncertain. Most observers have for this reason rejected it in favor of the screen method. If the screen is used the difficulty arises that there is no position in which it can be set in which the light can be cut off from *all parts of both* zones *simultaneously*. Thus, in Fig. 4, if we place the screen at N (the position given by theory for infinitely narrow zones) the light will be cut off simultaneously from the *outer* edge of A and from the *inner* edge of A', leaving the inner edge of A and the outer edge of A' still light. If we put the screen at e the light will be cut off simultaneously from the *outer* edges of both A and A', but nearly the whole remaining portion of A will remain light when the whole of A' is dark. If then one optician should choose his focal point by confining his attention to the cutting off of the light from the centers of the two zones, while another uses as his criterion the simultaneous disappearance of the light from the two edges, either outer or inner, the measurements of the two would differ on the same mirror by more than 20 per cent. To most opticians neither of the above tests would be quite satisfactory, and the majority would probably choose a point somewhere between the points N and e. Their measured aberrations would therefore be larger than the theoretical values, and if the mirror should be figured so as to make the two agree, it would, as a matter of fact, be under corrected; *i. e.*, the surface at the edge would be of too short a radius of curvature. This result agrees perfectly with the long experience of Mr. McDowell who has found that in every case in which the figured surface was in error, the error was in just this direction.

In all of the above cases we have assumed that in the operation of testing the different zones the radiant point and the

screen (or eyepiece, if the latter is used) are mounted on a common support so as to move together. If, as is frequently done, the radiant point is kept in a fixed position for all the zones and the screen or eyepiece only is moved, the differences between the focal points for the different zones and the aberration of the figured surface will be twice the amounts given by the above equations (11) and (12). This is readily seen by remembering that when an object and image are situated at the principal conjugate foci of an optical surface (either lens or mirror) any movement of the one outside the focus is accompanied by an equal movement (within small limits) of the other in the opposite direction. Hence if the conjugate focal distance changes as in this case, and one of the points remains stationary, the other moves a distance very nearly equal to twice the change. This can be readily expressed in analytical form. We have

$$\frac{1}{F} = \frac{1}{f_0} + \frac{1}{f_0} \tag{16}$$

where F is the principal focal length, and f_0 the principal conjugate focal length.

For another surface of focal length $F + \Delta F$ we have

$$\frac{1}{F + \Delta F} = \frac{2}{(f_0 + \Delta f_0)} \tag{17}$$

But if one of the points remains as before at f_0 we must also have

$$\frac{1}{F + \Delta F} = \frac{1}{f_0} + \frac{2}{f_0 + z} \tag{18}$$

and by comparing (17) and (18) we readily find

$$z = 2\Delta f_0 \left(1 + \frac{\Delta f_0}{f_0} + \left(\frac{\Delta f_0}{f_0}\right)^2 + \ldots\ldots\right) \tag{19}$$

For a maximum variation $\Delta f_0 = \frac{y^2}{4F} \cong \frac{y^2}{2f_0}$ equal to the maximum aberration of the surface, we have

$$z = 2\Delta f_0 \left(1 + \frac{y^2}{2f_0^2} + \ldots\ldots\right) \tag{20}$$

For a value of $\frac{y}{F} = \frac{1}{8}$ (which is about a maximum) the second term in the above parenthesis amounts to less than 0.002 or about two tenths of one per cent. An error of this amount in the measurement is negligible. Hence no error will be introduced even on the mirrors of very largest aperture by moving the screen alone (or the lamp alone) in the measurement.

In the same way we can readily determine how near the radiant point must be placed to the principal conjugate focal point of any part of the mirror. Suppose that instead of being placed at f_0 the radiant point is placed at a distance f_1 from the mirror. Then the image is formed at a point f_2 and we have

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} \tag{21}$$

For a variation in F, f_1 remaining fixed as before

$$\Delta f_2 = \frac{f_2^2}{F^2} \cdot \Delta F = \Delta F \left[1 + 2\frac{f_2}{f_1} + \left(\frac{f_2}{f_1}\right)^2\right] \tag{22}$$

Suppose the radiant point be displaced from the principal conjugate focus by a distance z. Then as just shown $f_2 \cong f_1 + 2z$ and substituting we find

$$\Delta f_2 = 4\Delta F\left(1 + 2\frac{z}{f_1} + \frac{z^2}{f_1^2}\right) \tag{23}$$

The error committed in this case is twice that involved in the previous one. The actual amount however is still very small. Suppose we assume that the measurements can be made with an error of 2 per cent. Then, in order not to introduce an error larger than this in the placing of the lamp we must have

$$2\frac{z}{f_1} < .02 \qquad \text{or} \qquad z < .01 f_1$$

That is for a mirror of 50-in. principal focal length the lamp must be placed within one inch of the principal conjugate focal point in order not to introduce an error (due to this cause) of

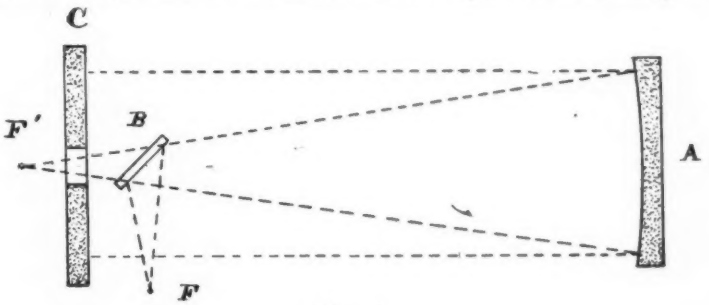


FIG. 5.

more than 2 per cent in the aberration, as measured by the movement of the screen alone. As has already been pointed out, the uncertainty in the determination of the focal point is likely to be much greater than this, and in a mirror of any considerable focal length, an error of several inches in the relative placing of the lamp and screen will not affect the measurements by an amount as great as the error of measurement itself.

It is readily seen from the preceding investigation that the Foucault method when applied to the testing of a parabolic mirror at the center of curvature is far less precise and satisfactory in its results than it is when used for testing at the principal focus.

It seems somewhat curious therefore that the former method should be so universally used in the case of specula, particularly as it is very easy to arrange to test the figured surface at the focal point instead of at the center of curvature. One method of doing this is shown in Fig. 5, where *A* is the mirror to be tested,

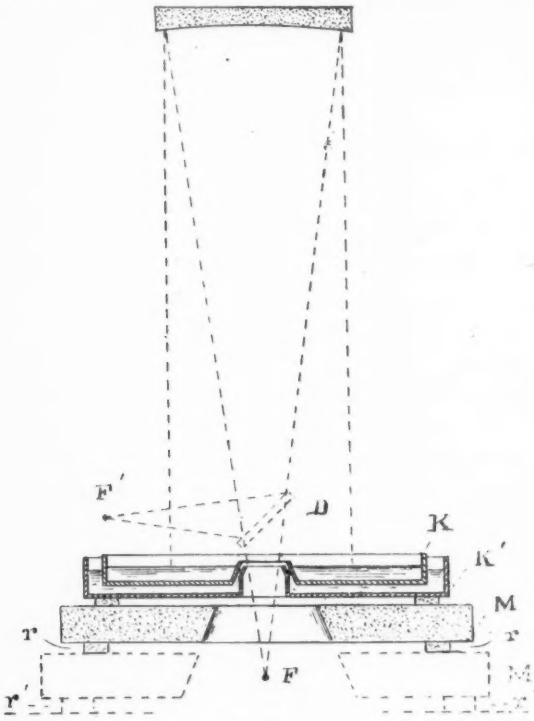


FIG. 6.

B a small flat, and *C* a large flat arranged in front of the mirror as a collimator exactly the same as in testing an objective. The radiant point and screen or eyepiece are placed at *F* in the principal focus of the mirror *A*, the image of the former being formed by reflection from the flat collimator *C*. If the latter has an opening at the center the flat *B* may be dispensed with and the radiant point and screen placed at F' just behind *C*.

If a large flat is not available its place may be supplied by a large basin of mercury, as shown in Fig. 6. In this case we must have a vertical shaft equal in height to the focal length of the mirror to be tested. The mercury basin may be provided with a central opening and the radiant point and screen placed just below the same as shown in the figure. Or, to avoid the inconvenient position the observer would have to assume in this case, a flat may be used just in front of the mercury surface at *D*. To avoid waves and ripples on the mercury surface the basin *K* containing it must be so mounted as to guard against vibration. The best method of doing this is to float it in a second basin, *K'*, containing mercury or thick cylinder oil. The basin *K'* should rest on a massive slab, *M*, of stone or iron, placed on rubber blocks, *r r*. In some cases it may be necessary to use a second system of stone and rubber blocks, *M' r' r'*, but unless the building in which the test is being made is very unsteady this will be unnecessary.

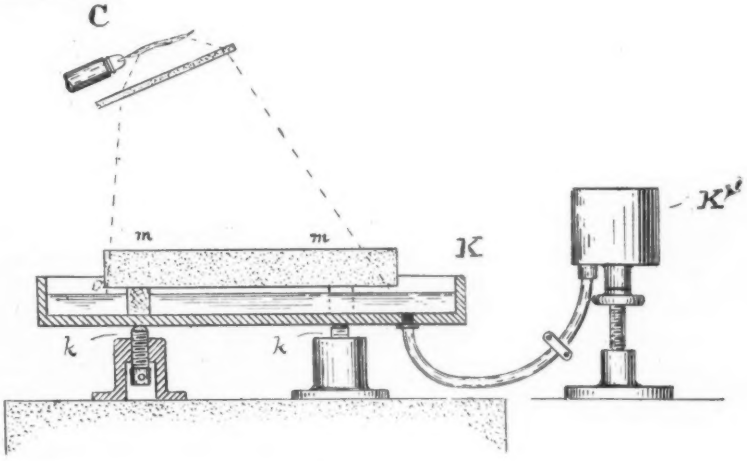


FIG. 7.

In this connection it may be of interest to describe another application of the free mercury surface of which little use has heretofore been made but which would seem to be of considerable value. Some years ago I suggested the use of such a surface as a test plane for the correction of large glass flats. Recently I have worked out a design of testing basin for this purpose which is very simple and convenient. It consists simply of an iron or wooden tank, Fig. 7, resting on three leveling screws, *k*. *k*. and

containing three blocks, *m. m.* on which is placed the glass surface to be tested. The mercury surface is adjusted to parallelism with the glass by means of the leveling screws *k*, which are supported on iron and rubber as before, and the distance between the glass and mercury is adjusted by varying the amount of mercury in the tank by raising or lowering the auxiliary tank *K'*, which is connected with *K'* by the rubber tube as shown. The surfaces are illuminated by a sodium flame *C*, so mounted that the light falls on them at nearly perpendicular incidence. Under such circumstances the phenomena of interference can be readily observed even when the distance between the two surfaces is several hundredths of a millimeter. A practically perfect test plane of any size desired is thus secured at small expense and the testing is performed without any actual mechanical contact taking place between the test plane and the tested surface.

ALLEGHENY OBSERVATORY, June, 1902.

REVIEW OF SOLAR OBSERVATIONS FOR THE YEAR 1901, AT ALTA, IOWA.

DAVID E. HADDEN.

FOR POPULAR ASTRONOMY.

The following results of solar observations made here during the year 1901 are in continuation of those contributed to POPULAR ASTRONOMY No. 95. The most notable characteristics of the record for 1901 are:

The sudden outburst of a large group during the month of May, at a time of absolute quiescence in a sunspot minimum cycle.

The marked increase in the frequency of spotless days, numbering 212 out of 269 days of observation, or nearly 79 per cent; compared with 52½ per cent in the preceding year.

January—The Sun's disc was free from spots during the entire month.

February—The disc was spotless all month, except a small spot which was visible from 4th to 9th.

March—During the first decade a couple of groups of small dots were present. Balance of month was spotless.

May—The first 18 days were spotless. On the 19th a fairly

large group had entered at the east limb in north latitude about 9° which completed the transit of the disc and disappeared by solar rotation in the late afternoon or night of 30th. On the day following its ingress it had increased in size to a remarkable extent being visible to the naked eye and consisted of several large, and numerous small spots; by the 22d the group was still increasing in area and fully 26 nuclei and small spots were contained in the disturbance. After passing the central meridian on the 25th the group assumed the two-spot type, the preceding one of which persisted until it reached the west limb, and the following spot gradually broke up into small dots. Coming after a comparatively long period of quiescence, during a sunpot minimum cycle, attaining its maximum area a few days after entering the visible hemisphere, and slowly diminishing during a second rotation to a mere dot, it was an interesting and noteworthy outburst.

June—Occasional dots were present during the first few days. Clear disc from 4th to 13th. On the 14th a return of the large group of May 19-30th as a couple of small spots in rather extensive faculæ; later only one spot remained which made the transit of the disc, disappearing on the 26th. The remainder of month was spotless.

July—With the exception of mere dots 22d-24th the month was spotless. Only slight faculæ were present from 11th to 14th and 21st to 25th.

August—On 2d a few short-lived small spots broke out suddenly, in rather high south latitude. The disc was spotless from 4th to the end of the month, except a small dot on 22d-23rd.

September—The tranquility of the Sun's surface was undisturbed by a single spot or facula during this month.

October—The disc was absolutely clear during the first five days.

From the 6th to 12th sporadic dots were visible. Another period of quiescence followed, until the 29th when some small spots appeared in the southern hemisphere which disappeared by November 2d.

November—Spotless from 3rd to 12th and from 25th to the close of the month. Between 13th and 24th a medium sized typical spot made the transit of the disc in south latitude.

December—The surface of the Sun was absolutely clear—free of spots or faculæ—on every observing day during the month.

The following table exhibits the numerical results of the observations for the year:

Months 1901	No. of Observing Days.	Average Number of			Aver. No. of Groups		Number of Spotless Days.
		Groups.	Spots.	Faculae.	N. Lat.	S. Lat.	
January	20	0.00	0.00	0.20	0.00	0.00	20
February	20	0.15	0.15	0.40	0.15	0.00	17
March	17	0.65	2.12	0.40	0.53	0.12	11
April	23	0.00	0.00	0.30	0.00	0.00	23
May	26	0.38	3.73	0.50	0.38	0.00	16
June	24	0.80	2.12	0.58	0.60	0.20	11
July	30	0.10	0.10	0.37	0.00	0.10	27
August	28	0.10	0.20	0.20	0.07	0.03	25
September	25	0.08	0.12	0.00	0.04	0.04	23
October	24	0.30	1.00	0.37	0.04	0.26	18
November	22	0.50	0.86	0.41	0.00	0.50	11
December	10	0.00	0.00	0.00	0.00	0.00	10

Compared with the preceding year there has been a marked decline—between 30 and 40 per cent—in the average number of groups, spots and faculæ during the year 1901. The number of spotless days has increased from 134 in 1900 to 212 in 1901.

In the subjoined table is given the annual average results for the years 1891 to 1901 for comparison:

Years.	Number of Days of Observations.	Average Annual Number of			Total No. of Spotless Days.
		Groups.	Spots.	Faculae.	
1891	257	2.9	14.9	3.6	24
1892	205	5.6	34.0	4.1	0
1893	177	6.6	36.6	4.1	0
1894	139	5.6	30.0	3.4	0
1895	149	5.2	30.5	3.5	0
1896	197	3.2	17.8	2.9	5
1897	198	2.2	11.0	2.3	29
1898	234	2.1	11.0	2.4	30
1899	259	1.1	4.8	1.5	108
1900	255	0.7	3.4	1.0	134
1901	269	0.25	0.9	0.3	212

ALTA, Iowa, July 1st, 1902.

A NEW METHOD OF TRANSITING STARS.*

MONROE B. SNYDER.

The method of observing transits of stars, here to be described in a preliminary and general manner, consists in driving the micrometer screw and hence micrometer thread of a transit instru-

* Reprinted from *Proceedings of American Philosophical Society*, Vol. XLI, No. 169. Read April 4, 1902.

ment by means of an electric motor at the uniform speed pertaining to any given declination, at the same time that the observer by secondary adjustment secures and maintains accurate bisection of the star, while given positions of the screw and hence thread are automatically recorded on a chronograph.

It is now more than four years since the writer described the method to his associates interested in astronomical observation. In the autumn of 1899 this plan of electrically driving the transit thread was also mentioned to Professors Wadsworth and Morley and at some length discussed with the latter. Working drawings of the special instrument which at present gives concrete expression to the method were completed in September, 1900. The "electrical transiter," or more simply "transiter," as for brevity the new device has been named, was mounted on the small meridian circle of the Philadelphia Observatory in February, 1901, and there subjected to many tests and improvements since. The demands on the writer's time have, however, not permitted that singleness of devotion which the transiter and its interesting method should receive, and it does not, therefore, seem desirable any longer to withhold a preliminary communication on the subject.

The fundamental idea of moving a transit micrometer wire by means of clockwork synchronously with the star's motion was proposed in 1865 by Braun.* But to Repsold is due the persistent pursuit of the idea that personal equation can be banished from transit observations by mechanical methods. And although his practical solutions of the problem have hardly proved adequate, they have stimulated and permitted serious efforts on the part of observers.

The first suggestion of Repsold,† made in 1888, was to mount the base of the transit instrument on a polar axis and within a limited range drive the instrument to the diurnal motion by means of clockwork, and in some undescribed manner keep the star bisected so as to determine the meridian passage through electrical signals automatically made. The plan admirably met the chief difficulty of the varying rate of motion due to difference of declination, but was abandoned on account of the great mass to be moved.

It has to the writer, however, seemed likely that by applying a powerful electric motor of strictly constant speed, and by using a

* Dr. Carl Braun, *Das Passagen-Mikrometer*, Leipzig, 1865.

† F. Repsold, "Durchgangs-Instrument mit Uhrbewegung," *Astron. Nach.*, 2828.

second electric motor with regular speed for driving one element of a differential gear which engages the shaft driven by the main motor, or by several other electrical devices not requiring mention, an equatorially mounted transit instrument can be driven to stellar bisection and readily kept so adjusted.

A second plan, "Neuer Vorschlag zur Vermeidung des persönlichen Zeit-Fehlers bei Durchgangs-Beobachtungen," was proposed by Repsold* in 1889 and tested by Becker† in 1891 with moderately favorable result. A new form of micrometer, made for the Madison Observatory by Repsold,‡ was described in 1896, and with the general plan of its construction the writer became acquainted in the autumn of 1897. The specially designed and rather complicated micrometer requires that star bisection shall be maintained by twirling the micrometer shaft alternately with each hand of the observer. While this twirling is proceeding the ten electrical contacts of a drum mounted on the micrometer screw determine as many records on the chronograph. This Repsold method, while not lacking in ingenuity, seemed to the writer to labor under the following defects: An alternating twirling motion of the micrometer, even when communicated with the greatest adroitness, is not approximately a uniform motion. The observer is attached to the instrument by both hands, and is incessantly committed to the most painful attention. Good results could hardly be secured without the most prolonged and painstaking practice. Through his special habit of twirling each observer must have a new form of personal equation. Even the averaging secured by the great number of electrical contacts does not certainly eliminate the peculiarities of a given habit of twirling. At any rate the great number of signals to be read from the chronographic sheet constitutes a very serious infliction on time and patience. Finally, the Repsold method does not, during any given star transit, offer a ready and direct means of comparison with the ordinary methods of observation.

The difficulties experienced in acquiring reliable observing habits with the Repsold transit micrometer are evident from the reports of Becker,¶ Kowalski,‖ and Flint§. The latter is, it seems,

* F. Repsold, *Astron. Nach.*, 2940, 1889, September.

† Professor E. Becker, "Ueber einige Versuche von Durchgangs Beobachtungen nach dem neuen Repsold'schen Verfahren," *Astr. Nach.*, 3036, 1891 März.

‡ "Neue Mikrometer von A. Repsold u. Sohne," *Astr. Nach.*, 3377, 1896, Juli.

¶ *Loc cit.*

‖ *Ueber das neue selbstregistrirende Mikrometer von Repsold*, Petersburg, 1897.

§ Albert S. Flint, "The Repsold Micrometer of the Washburn Observatory," *Astron. Jour.*, No. 470, 1899, September.

the only American observer who has tried the Repsold device to any extent, and he says that "after considerable practice" he obtained the same probable error by the method for "a signal under good conditions as for a single thread when observing with a fixed reticule and chronograph."

And yet it is not surprising that among European observers engaged in longitude work, the Repsold method should after prolonged discipline yield excellent results. Albrecht,* in an extended paper on its application to longitude work, points with enthusiasm to the superior results obtained. He considers the former indifferent results to be due to lack of practice and insists that the highest effectiveness, by this method, is attained only after a long season of active experience. "Man erlangt das Maximum der Leistungsfähigkeit doch auch bei dieser Methode erst nach langer Uebungszeit."

These experiences of practiced observers, while pointing to the value of the plan of micrometer thread motion in eliminating personal equation and its variations, confirm the anticipations of the writer as to the inherent defects of the Repsold method. It is therefore interesting to note that experiments for relieving some of the imperfections of the method have been going on at the Könisberg Observatory, where its Director, H. Struve,† has successfully applied clockwork directly to the Repsold micrometer, and thus unquestionably improved its usefulness. With this work the writer became acquainted only after his own plan had been consummated and the resulting instrument constructed and mounted for use. Dr. Cohn,‡ of the same Observatory, has recently published an extended investigation which shows marked advances in accuracy over the usual methods of observing. Struve's method has, however, thus far involved the unsymmetrical placing of the weight of the apparatus and, while itself possessing serious mechanical limitations, does not avoid certain peculiarities and limitations of the Repsold micrometer. The necessity therefore still exists for a method that shall be flexible in adaptation and use, and not impose unreasonable conditions on the observer.

* Professor Th. Albrecht, "Die Beobachtungsmethode mittelst des Repsold'schen Registrirmikrometers in ihrer Anwendung auf Längenbestimmungen," *Astron. Nach.*, 3699, 1901, März.

† H. Struve, "Ueber die Verbindung eines Uhrwerks mit dem unpersönlichen Mikrometer von Repsold," *Astron. Nach.*, 3719, 1901, März.

‡ Dr. Fritz Cohn, "Ergebnisse von Beobachtungen am Repsold'schen Registrirmikrometer bei Anwendung eines Uhrwerks," *Astron. Nach.*, 3766-67, 1901, November.

The conditions to be attained in an effective method were early formulated by the writer substantially as follows:

The ordinary micrometer of a transit instrument shall be used, and its movable wire driven electrically at approximately uniform speed. The rate of driving shall, as required, vary with the declination. The direction of the motion shall be instantly reversible. The wire shall be promptly readily started on its course when bisection of the star occurs. While in motion the wire shall be easily regulable for bisection of the star. The automatic chronographic record shall be made at whole turns or at fractions of a turn of the screw as desired.

In practically studying the electrical method of determining and controlling the motion of the thread of a transit micrometer, it has been found that there are three principal plans of adaptation available:

I. A small electric motor may be placed on or near the head of the transit instrument, with its axis parallel to that of the instrument. The varying rate of motion required for change in declination may then be secured by regulating the field of the motor and, if necessary, also that of a small dynamo supplying the current. The main difficulties in this plan are, the wide range of speed regulation and the interference due to inertia at starting.

II. Equatorial speed that is absolutely constant but slightly regulable may be given the motor, similarly placed, and the differing rate of motion proper to each declination determined by mechanical gearing, consisting principally of two friction disks placed at right angles to each other, or by some other mechanical equivalent. Both of these plans require special care in the construction and mounting of the motor, so as to obviate the communication of injurious vibration to the transit instrument.

III. It may in some instances be desirable to place the electric motor on a separate support near the base of the instrument, and then by means of a light steel shaft entering the axis of the transit finally communicate the required motion to the micrometer screw. All the motion and controls peculiar to either of the other plans may be secured to this form of transiter, excepting that the micrometer cannot at all be driven during the time necessary for reversal of the transit instrument. The limitation would in some instances be rather annoying, if not destructive of facilities the method should furnish.

It is also quite feasible to place certain elements of the transiter on a separate support and communicate the motion to a small slow-speed alternating current-motor placed on the head of the

transit instrument and connected with the micrometer, and so obviate practically all the mechanical and electrical difficulties. Experiments in this direction are in progress.

In the attempt made to actualize the electrical method of driving the transit micrometer contending obstacles and facilities led, for a first trial, to the selection of the second plan mentioned, namely, that of gearing from a small motor of fixed speed placed near the head of the instrument. In reaching this conclusion the writer was greatly assisted by his friend and former student, Dr. H. G. Geissinger, who, immediately the method of the electrical transiter and the conditions it imposed had been described, became enamored of the delicate mechanical and electrical problem. Detail drawings of a transiter of this type were prepared under the writer's direction by Dr. Geissinger, and he has introduced several ingenious devices which admirably meet the conditions set. The special aim of the writer is to construct a form of transiter that may, without serious modification, be attached to any transit instrument. It should not involve a special form of micrometer nor in any way vitiate the instrument for its usual work however accurate. Excepting in the unnecessary weight of the parts and general coarseness of the mechanism, the transiter as now constructed fairly meets all the demands originally set and besides introduces some new conveniences. Although it is not the intention at present to give a detailed description of the transiter it may be allowable briefly to mention several of its advantages:

Regulation of the bisection of a star is easy and definite. A record is made but once for each revolution of the micrometer, and records will be increased in frequency only as special work demands. A predetermined schedule of recording can be determined for any given run of the micrometer. Back lash of the screw on reversal of motion may be completely eliminated by the adjustment of the electrical contacts. The whole transiter may be balanced symmetrically on the instrument, and thus changes in the instrumental constants avoided. Instantaneous reversal of the motion of the micrometer permits of many conveniences as to method of work. In determinations of time and longitude the tendency has of late been to reverse the transit instrument during the passage of each star, and thus to eliminate a series of errors and facilitate reductions. The transiter by its ability to reverse motion instantly, and even automatically, lends itself readily to this method of work.

From the beginning of 1901, when it was completed, until the present the transiter has been the subject of many tests and of

some improvements, and for a year or more it is hoped it may be destined to progressive change. It is now mounted on the four-inch meridian circle, for which it is expected a suitable place may be found at the Suburban Photographic Station of the Observatory, when this Station shall have been definitely located, but only after the completion of the present series of experiments with the transiter, and the determination of the latitude and longitude of the City Station of the Observatory.

Personal equation in all its variations remains a much more serious factor than many painstaking astronomers, who have not sufficiently practiced their accuracy even against a simple personal equation machine, are willing to admit. It is then gratifying to find that Professsor Langley* has recently been willing to propose an entirely novel and highly suggestive method for its elimination in many classes of observation. And it may therefore be permissible, in this presence, to draw attention to the fact that the method of the electrical transiter permits for the first time the determination of the absolute personal equation at any and every desired star transit, and on the star itself. While reserving a complete discussion of this subject for a future occasion, it should be stated that several plans offer themselves to this end in the transiter. To mention but one: The usual wires are undisturbed, and the transiter can be adjusted so as to cut itself in and out automatically at certain parts of the run and only there receive the attention of the observer for star-bisection. At other portions of the run the usual method of chronographic signals, or even of the eye and ear method may be employed, and so, on reduction to the middle, be compared with the transiter's automatic signals. Personal equation may thus be studied with facility on the stars themselves and its variability traced through a simple observation or a series of observations, and whatever is sufficiently stable expressed as a function either of the stellar declination or of stellar magnitude or even of the physical condition of the observer.

It seems rather likely that finally all such study of the personal equation, when it shall have clearly demonstrated the unreliable character of the usual methods of transit observation and the adequate accuracy of the newer method, will be relegated to the Psychological Laboratory. Certain it is that the banishment of

* Professor S. P. Langley presided at the meeting, and had at a recent meeting of the American Astronomical and Astrophysical Society described his new and very ingenious method of obviating personal equation in any time observation.

reaction time from transit observations and the reduction of this class of errors to those of bisection, either of a star image by a thread or of a thread interval by a star, means an epoch in observational astronomy whose actual realization by suitable devices is a worthy challenge to our best efforts.

With an automatic transiter allowing easy and accurate bisections, a chronograph recording with the utmost accuracy, and a clock of the best mechanism kept under constant pressure and temperature, a new field for accurate work in longitude determination and in the evaluation of stellar position and stellar parallax would be opened to the activity of the astronomer.

PHILADELPHIA OBSERVATORY, March, 1902.

ARE OTHER PLANETS INHABITED?

D. G. PARKER.

FOR POPULAR ASTRONOMY.

In discussing the plurality of worlds and the habitability of planets other than our own we will assume that no line of reasoning can be safer or more convincing than that of analogy, and while we have no right or disposition to limit possibilities of the great creative power, it is certainly unscientific to raise presumptions not supported by mathematical data, nor warranted by laws of nature as we find them revealed upon our own planet.

A distinguished writer* doubtless voiced the weight of opinion when he said:

"We must believe that our terrestrial types of life are universal types, and no naturalist will now hazzard the surmise seriously, that life is anywhere possible under conditions which would render it impossible upon the Earth."

We will limit our inquiry to the human type of life, and that this is not adapted to every condition and environment is demonstrated by the fact that vast sections of our own globe such as the great deserts and the high polar regions are utterly uninhabitable, while the higher order of intellect is confined to comparatively narrow limits.

We know that tropical heat begets stupor and sluggishness on one hand or intemperate excitement and passion upon the other, while if we turn to the higher latitude of the arctic circles we find no native intelligence above that of an Esquimo.

* Professor G. Seneca Jones, POPULAR ASTRONOMY, May 1891.

Of all created beings man is the most refined and sensitive, and while his genius enables him to plan artificial protections in carrying out migratory or exploration schemes, he is by nature confined within the narrowest limit.

Then in discussing the habitability of other worlds, let us assume that we are referring to this sensitive man who does not differ materially from ourselves. Here we will find the question simplified by putting ourselves in his place. Could *we* live on any one of the other planets in our solar system without an environment of such conditions as would prove fatal?

We must assume the Sun to be the initial source of heat, and that this sustains life in whatever form we find it. Our mathematics convinces the judgment that radiation must be in proportion to distance, and it is highly speculative to assume that local conditions would change this general law governing temperature.

Considering this, as also light density, may we not dismiss the whole outer group? On the other hand the close proximity of Mercury to the Sun make the burdens of human life there, equally unbearable.

The only two planets remaining which invite even a speculation are those next to us on either side.

We will consider the more distant first, and admit at the outset that the scientific world seems hopelessly divided upon the problem of Martian life. There is much abtruse reasoning based upon presumed possibilities, but it simplifies our inquiry that all are substantially agreed upon actual discoveries.

It is upon these admitted facts that we take the negative side. Passing over the fascinating philosophy of Flammarion, Proctor and others, the discovery of Schiaparelli's canals were at first hailed as convincing proof of human workmanship, but this argument was dashed to pieces by micrometrical measurements which showed these lines to be from 20 to 70 miles wide, and in some cases more than 2000 in length.

That these are irrigated strips of land made green and productive by liberated waters of melting polar ice caps, seems equally untenable. It is true that the changing colors give this theory a look of plausibility. But when we consider what such a theory really involves, one may well hesitate before accepting it.

Who can seriously contemplate transformations the magnitude of which have no parallel upon this globe. How can we accept the proposition of winters so severe as to form ice caps 70 degrees of arc, followed by summers so tropical as to melt them all away, flooding vast regions far beyond the central zone. Not

that the severity of the winter can be doubted, but that it should be followed by a season of so high temperature while receiving only 43 per cent of the Sun rays which we enjoy, seems wholly improbable.

The claims of those who picture such water supplies under so high temperature, are irreconcilable with other known facts. It is admitted that the planet is without any large bodies of water such as our oceans and seas; that the atmosphere is very light,—less than half the density of ours, even at the highest mountain peaks. This cannot be doubted, as unlike other planets, Mars is seen to the very surface of the ball. If there were water vapors they would condense into clouds, and these would obscure the observation.

To create such polar snows and ice-caps as are claimed, presupposes an atmosphere freighted with aqueous vapors, and it would seem that such clouds could not fail to be detected.

That such plentiful supplies of watery vapors do not exist is further proven by the fact that there is substantially nothing to originate them. It takes the evaporations of large bodies of water to distribute the needed moisture for sustaining plant and animal life. This is proven from our own experience.

Three-fifths of our globe is deeply covered with water; evaporations from this are daily carried into the atmosphere in immense quantities and taken by the winds for distribution over the planet. Even this is found to be insufficient, for vast deserts continue arid and parched and yield no fruitage whatever.

If this is our experience, what must it be upon Mars where no such bodies of water exist to be vaporized.

The nebula hypothesis seems to afford the only theory by which the secular changes going on, can be explained, and the scientific world is settling down to a conviction that this theory with perhaps some modifications, must be accepted.

Of the many views expressed, perhaps those of LaPlace best appeal to the judgment and have the larger following. Assuming his reasoning to be substantially true it follows that Mars is older than Earth by perhaps millions of years. Now using the best data obtainable we find that probability fixes a comparatively limited period for man's existence upon any one of the heavenly bodies, presuming as we may that some of them, includ those of other systems, are peopled at some period of their existence.

Geology proves conclusively that between the chaotic beginning and the time when Earth through many convulsive changes

was prepared for the reception of man, countless years must have intervened, and we may assume that in the long cooling process our globe will reach a period in a comparatively near future, when all life will cease to exist, the planet still continuing its orbital flight through unnumbered ages, dead, cold and silent, so that man's existence upon any one of the heavenly bodies may be presumed to take in a comparatively brief interval of time: how brief, we cannot determine in years, but a few facts may lead to approximate conclusions.

The record of animal and vegetable life as written in Earth's stony crust, reads like an open book. From it we learn the exact order of introduction, and from it man appears at the very apex of the great column, the intellectual Brobdignagian, but the physical Lilliputian, of all the long line of incoming orders.

And even since his introduction how marked the changes; constantly advancing in intellectual force and refinement, but as constantly deteriorating in physical strength and vigor.

We have no written record back of Bible chronology, but the longevities therein mentioned lead to the thought that generations have steadily shortened from an average of about 155 years, down to 33 as at present.

This gives us some data of calculation though we may admit, many elements of uncertainty.

The great majority of scholars incline to the opinion that man's existence upon this planet will approximate 50,000 years*, though high authority limit his time to within 10,000. Even accepting the highest term, it seems fair to presume, considering the effemination of the race and shortened life since history has been written, that his continued existence cannot exceed another 30,000. Altogether, say, 80,000 years. A brief span in the life of a planet.

Now keeping in mind the nebula theory and applying the same principles to Mars, we will find that that planet must have passed the condition of man's existence long before Earth entered upon it.

This line of argument assumes that the planet might have once been inhabited, but that age with departing heat and atmosphere have carried it beyond that period, though even this assumption must be modified by expression of doubt as to whether there ever was a time when conditions favored a race similar to ourselves. His inferior weight would rob him of an

* See Am. Enc. Dic. and authorities cited.

essential characteristic on one hand or his radically increased size would be equally disastrous upon the other.

But the inquiry relates to the present and our conclusion that the planet is not inhabited rests upon these premises.

1. The moisture, if any, is insufficient. It is admitted that there are no large bodies of water to be vaporized and the telescope practically demonstrates that there are no clouds suggestive of either snow or rain precipitations.

2. Without abundance of moisture there would be insufficient vegetation to sustain life.

3. It is too cold. With a temperature presumably two and one-half times lower than our own, no life known to us could survive: nor does it help the matter to assume, as some have, that there is a blanketing process of heat storage, when facts demonstrate that there is no such blanket.

4. Accepting the LaPlace theory of relative age if man has ever dwelt upon that distant world, the period of his allotment has doubtless long since passed.

5. But the most convincing proof lies in the fact of its greatly rarified atmosphere: being generally admitted to be 100 per cent lighter than ours, even at the highest mountain peaks. Man lives substantially on nitrogen and oxygen and here we find his supplies practically cut off.

Professor Lowell, though an affirmative advocate, after reviewing conditions of the atmosphere is impelled to admit that "Beings physically constituted like ourselves, would be liable to meet with severe discomforts."*

Is not this a fatal admission? How can life be long perpetuated under conditions of unbrokenly "severe discomforts?" To suppose that life exists at all under such dissimilar conditions is to speculate upon some sort of organism having no analogy to our own, and about which we know nothing.

While it may hardly be consistent with the dignity of scientific investigation to rest a conclusion upon the opinion of others, it is nevertheless interesting to know that some of these reasons have had weight with many of the best minds of the present age. Want of space will forbid quotations, but we invite attention to recent utterances of Professors Newcomb, Young, Holeman and others.

Passing to the planet Venus the conclusion is also on the negative side. If the theory is correct that Mars was born into the planetary family long before Earth, it follows that Venus must

* Popular Astronomy, Dec. 1894.

have appeared proportionally long afterwards. In fact there are indications that this planet is now passing through the storm period of its primitive crusting. This is suggested by the hazy, nebulous or steamy atmosphere which seems to shut out all satisfactory observation, notwithstanding it is the nearest to us of all the major planets. There is a fruitful field for speculation, however, as to the future.

Let us go forward in imagination through eons of time to a period when it shall have reached the age of present conditions upon Earth. May we not presume from its present dense atmosphere a condensation and precipitation into large bodies of water as we have them, yielding substantially the same results through evaporations and air currents?

The closer proximity to the Sun will be largely offset by the increased age and shrinkage of the latter, making temperature, possibly not much, if any, higher than Earth's at the present time.

Verdure may be found widely distributed and the planet being of about the same volume and density of our own gravity will not materially differ; hence the race of men who inhabit that body long after they become extinct upon Earth, need not be inferior in size, weight, intellect, or pleasurable emotions.

A NEW ALGOL VARIABLE. +45°4101.

EDWARD C. PICKERING.

A striking illustration of the value of the library of glass photographs collected at this Observatory during the past seventeen years has been shown within the last few days. Comet *a* 1902 was discovered by Dr. Brooks on April 14, and it was found that a photograph had been taken here on April 3 with the 8-inch Draper telescope, approximately in the direction from which the comet came. An examination of this plate was accordingly made by Mrs. Fleming, superposing it upon another plate of the same region taken with the same instrument on March 7, 1900. No trace of the comet was found, and in fact the elements now indicate that it was a little beyond the region covered by the photograph. One star, however, in the constellation Lacerta, according to Heis, but in Cygnus according to the Uranometria Nova, appeared faint on the early plate and bright on that taken later. A further examination showed that this object was the north preceding component of + 43°4101. Its position for 1900

is R. A. = $21^h\ 55^m.2$, Decl. = $+ 43°\ 52'$. The difference in right ascension of the two components is about $2^s.0$, the difference in declination, $0'.3$. A further examination showed that the star was generally bright and constant in light, so that it must be a variable of the Algol type. It is not very distant from the remarkable variable star SS Cygni which precedes it 16^m, and is $44'$ south. This last star was discovered at this Observatory in 1896 and is ordinarily faint, becoming suddenly bright at intervals which appear to be irregular. Only one other star, U Geminorum, is known to undergo similar changes. The star, SS Cygni, has been carefully studied here, several hundred photographs having been taken of it. It has also been observed visually on several hundred nights both here and elsewhere, but as yet the law regulating its outbursts of light has not been discovered. Again the advantage of the photographic method is indicated, since each plate taken for SS Cygni can be used for studying the new variable, or any others that may be discovered in this part of the sky, as well as if taken for each alone, while of course the visual observations of SS Cygni can be used for no other star. The total number of plates showing the new variable at full brightness is 388, of which 1 was taken in 1889, 10 in 1890, 12 in 1891, 8 in 1892, 9 in 1893, 3 in 1894, 10 in 1895, 37 in 1896, 184 in 1897, 30 in 1898, 37 in 1899, 28 in 1900, 7 in 1901, and 12 in 1902. Besides these, the star appears on 54 photographs taken with the 2.5 inch Anastigmat, but they have not been included in the present discussion, since the proximity of the other component in some cases renders it difficult to decide whether the variable is at its full brightness, or not.

Besides these plates, 19 were found on which the variable, which ordinarily has the magnitude 8.9, was of the magnitude 9.3 or fainter. They are enumerated, together with six others taken later, in Table I, which gives in the first three columns the year, month and day, the Greenwich mean time of the middle of the exposure in hours and minutes, and the Julian Day and thousandths. The fourth column gives the photographic magnitude, and the fifth, the correction to the minimum corresponding to this magnitude. A positive sign denotes that the photograph was taken before minimum, a negative sign, after. When the star was not seen, the plus and minus sign is used to indicate that the correction may have any value within the limits given. Thus, the star was of the magnitude 10.5 for about $0^d.71$ before and after minimum, and accordingly any correction between $+ 0^d.71$ and $- 0^d.71$ may be applied to the ob-

served time of the second plate without indicating an error in the observation. All of the values are derived from the light curve found as described below. At first the period was thought to be $1^d.498$, but this was found to be an error. The true period appears to be about $31^d.304$, and the times of minimum are represented by the formula, $2{,}410{,}015.05 + 31.304E$. The value of E, and the residual found by subtracting the computed time of minimum from the time of the photograph, are given in the sixth and seventh columns. The eighth column gives the corrected residual found by taking the algebraic sum of the fifth and seventh columns. The letter F is inserted when the variable was invisible, and the phase is less numerically than the correction given in the fifth column. In these cases, no correction to the period is indicated. The letter M is inserted when the phase is less than $\pm$ 0.45 and the variable is of the magnitude 11.4, or fainter, since it is then near minimum and is varying so slowly that an accurate correction cannot be obtained.

It will be seen from the last column of the table that all the magnitudes are nearly represented by the formula, except those derived from photographs taken on J. D. 1962, and 4431. On these dates, the star was at nearly its full brightness, and the deviations which amount to 0.4 of a magnitude are probably due to error of observation.

TABLE I.

OBSERVED MINIMA OF + 43°4101.

Y.	M.	D.	G. M. T. h	m	J. D. d	Magn.	Corr.	E.	Phase.	Corr. Phase.
1891	8	17	9	121	1962.806	9.28	— 0.99	62	+ 6.908	— 5.92
1892	10	22	3	131	2394.563	<10.5	± 0.71	76	+ 0.409	F
1895	9	20	5	124	3457.642	9.31	+ 0.98	110	— 0.848	+ 0.13
1896	9	30	1	142	3833.487	10.52	+ 0.71	122	— 0.651	+ 0.06
"	"	"	9	120	3833.806	<11.5	± 0.43	"	— 0.332	F
"	10	1	3	135	3834.566	11.49	— 0.43	"	+ 0.428	M
"	"	31	2	115	3864.510	9.64	+ 0.90	123	— 0.932	— 0.03
"	"	"	4	105	3864.587	10.02	+ 0.83	"	— 0.855	— 0.03
"	12	3	2	147	3897.533	9.85	— 0.86	124	+ 0.787	+ 0.07
1897	1	2	10	51	3927.452	10.85	+ 0.64	125	— 0.598	+ 0.04
"	4	6	20	59	4021.874	<11.7	0.00	128	— 0.088	F
"	5	7	19	34	4052.815	11.54	+ 0.36	129	— 0.451	— 0.09
"	9	9	15	16	4177.636	10.02	— 0.83	132	+ 0.846	+ 0.02
1898	1	13	11	02	4303.460	11.69	0.00	137	— 0.238	M
"	5	21	20	04	4431.836	9.28	— 0.90	141	+ 2.922	— 1.93
1899	8	30	12	46	4897.532	9.28	+ 0.99	156	— 0.942	+ 0.05
1900	3	7	21	43	5086.905	10.95	— 0.60	162	+ 0.607	+ 0.01
"	8	9	20	13	5241.842	9.74	+ 0.89	167	— 0.976	— 0.09
1904	8	21	15	32	5618.647	<10.6	± 0.69	179	+ 0.181	F
1902	4	28	17	44	5868,739	11.54	+ 0.36	187	— 0.159	M
"	"	"	18	18	5868.762	11.44	+ 0.46	"	— 0.131	M
"	"	"	19	07	5868.797	11.44	+ 0.46	"	— 0.106	M
"	"	"	19	37	5868.817	11.49	+ 0.44	"	— 0.081	M
"	"	"	20	20	5868.847	11.44	+ 0.46	"	— 0.051	M
"	"	"	20	34	5868.857	11.44	+ 0.46	"	— 0.041	M

The form of light curve may be determined by plotting the magnitudes and phases given in the fourth and seventh columns. The star retains its full brightness for 28 days, its photographic magnitude at maximum being 8.9 About a day before the minimum it begins to diminish, attaining the magnitude 9.0 at $1^d.05$ before minimum, 9.5 at $0^d.94$, 10.0 at $0^d.84$, 10.5 at $0^d.71$, 11.0 at $0^d.58$, and 11.5 at $0^d.43$. The light remains nearly constant for more than half a day, with the minimum magnitude 11.6. The time of increase is more uncertain, but apparently is nearly the same as that of decrease. The period of this Algol star, 31.4 days, is more than three times that of any other as yet discovered, and the duration of minimum, 2 days, is double that of S Cancri, the next in length. The period of S Cancri is 9.5 days, and the duration of minimum 0.9 days. The last minimum of $+43°4101$ occurred on April 28, 1902, at $21^h 33^m$ G. M. T. The predicted times of the next minima are May $30^d\ 4^h\ 51^m$, June $30^d\ 12^h\ 8^m$, July $31^d\ 19^h\ 26^m$, September $1^d\ 2^h\ 44^m$, and October $2^d\ 10^h\ 2^m$, 1902.

The anomalous variations of Schwab's variable, described in *Circular* No. 64, were explained by the period, 3.38 days, cabled by Professor Kreutz, and announced in our *Bulletin* of February 3, which also stated that the careful watch of this star, proposed in the *Circular*, would therefore not be necessary.

HARVARD COLLEGE OBSERVATORY,
Circular No. 65, May 6, 1902.

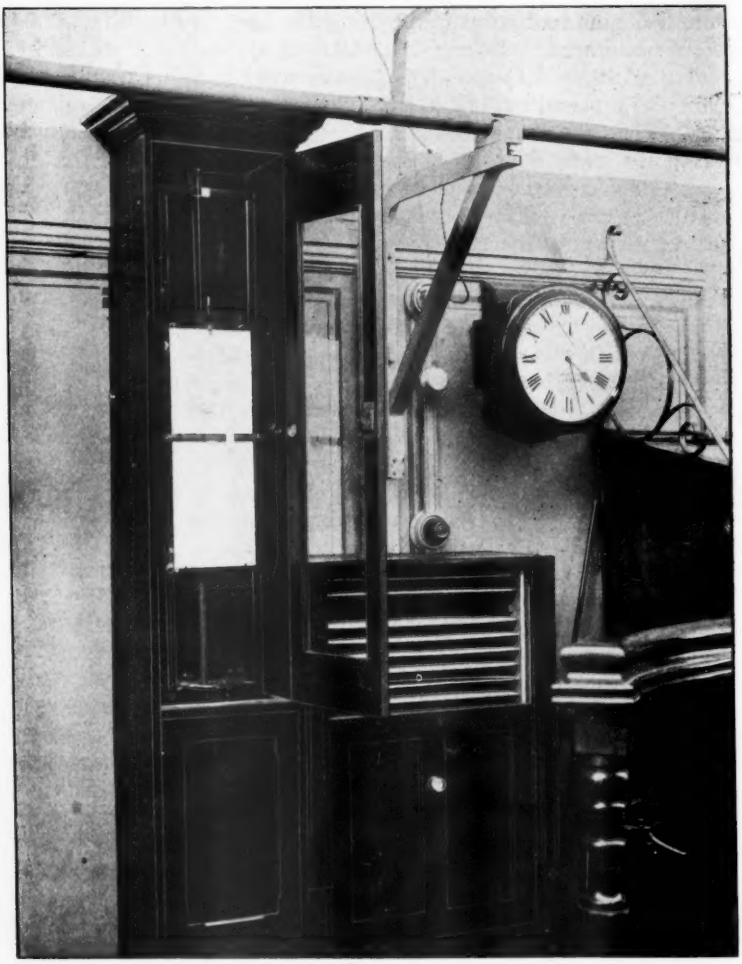
A DEVICE FOR FACILITATING MERIDIAN CIRCLE SETTINGS.

W. ERNEST COOKE.

FOR POPULAR ASTRONOMY.

It is of course gratifying to find that the star correction machine designed by Professor Turner and myself and described by Professor Wilson on p. 82, February number of POPULAR ASTRONOMY 1902, has been found quick and accurate in practice. This method of computing the corrections has, however been superseded by Turner's tables. I quite agree with Mr. Wilson's contention that the work is machine work, and at the time that my own machine, almost identical with that figured on page 83, was engraved by Messrs. Troughton and Simms I was ready to back my computations, both in speed and accuracy, against those made by any other method. When, however, Professor Turner commenced his warfare against the use of an

unnecessary number of figures, and published his reduction tables, using only three places of decimals, I found that reductions could be performed more expeditiously with the help of these than even



A Device for Facilitating Meridian Circle Settings.

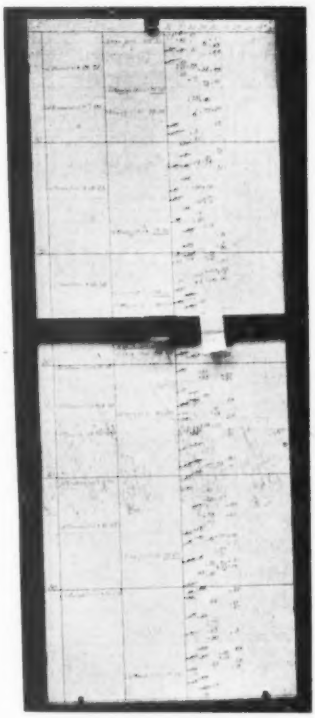
with the machine, and this latter is now placed away in a glass case as an interesting curiosity.

In connection with this subject of mechanical aids to observa-

tory work I should like to call attention to two machines which I still find useful and have not yet placed in the glass case just alluded to.

One of these is for computing the refraction correction to be applied to stars observed with the transit circle.

It is described in the same volume as my star correction machine. *The Monthly Notices of the R. A. S.*, Vol. LV, p. 515. By means of this the correction is read at a glance. No computation whatever is necessary and the only mechanical operation required is to set two slides, one for barometer and the other for temperature. This is done for the first star to be reduced and an occasional touch of a screw is the only operation required for the remainder of the evening's work.



ALUMINIUM SHEET.

My second "Observatory comfort" is designed to facilitate transit settings. In the first place the rim of the large circle of the meridian instrument is graduated into spaces of 10′ and each degree is numbered. A fixed horizontal black thread is placed across the rim at a convenient height and the graduations on the rim of the circle are so arranged that the spot crossed by the fixed thread always indicates the *declination* of the star at which the telescope is pointing. There is nothing specially new in this of course but it is far superior to the vernier and bubble so frequently used for setting purposes.

Now as to the main design. The working list of stars to be observed may be conveniently arranged in three groups, clock stars, azimuth stars, and others. At present my "others" consist of zone stars for the International Photographic Durchmusterung, so I shall refer to this division as "Zones."

I take a sheet of aluminium (using this simply because it is light and easily handled) 7½ x 20 inches, and cover it with draw-

ing paper. I divide the sheet longitudinally into three spaces and laterally into 60. This entire sheet represents 1^h in R. A., each subdivision being of course equal to 1^m. I now plot my stars at the proper R. A., putting clock stars in the first longitudinal division, azimuth stars in the next, and zones in the third stating the name of the star, magnitude and declination. For the zones I use symbols. I make 24 of these sheets, one for each hour and place them away in a convenient cupboard, each heste having a little shelf to itself.

Alongside this cupboard is a clock work carrying a skeleton frame into which one of the aluminium sheets will just fit and the clock carries the sheet through its own length in one sidereal hour. Across the centre, on a level with the eye, is a fixed straight edge, capable of a small adjustment by means of a milled screw (shown in the accompanying photo on the side of the case).

In starting work the sheet for the proper hour of R. A. is placed in the frame and set so that the correct minute and second of sidereal time come opposite to the straight edge (the lower edge of course), and the clock "does the rest." A single glance at the sheet shows what stars in each group are just coming on. I shall not attempt to indicate the comforts of this arrangement to professional astronomers as they are so self evident.

THE OBSERVATORY, Western Australia,
1902, March 14.

THE MOON AND THE WEATHER.

ARTHUR K. BARTLETT.

FOR POPULAR ASTRONOMY.

There is a popular and almost universal belief that the Moon has a potent influence on changes in the weather, and most persons have become so strongly impressed with this idea that it is difficult to explain the subject correctly or convince them to the contrary. The notion that the Moon exercises an influence upon the weather and climate is really an old superstition, and has few, if any, advocates among scientific men of the present day. There is no reason whatever for imputing to our satellite even the slightest change in the weather, and the supposition that the Moon can affect our atmosphere to such an extent as to produce storms, is at present confined mostly to those who are unacquain-

ted with the teachings of science. While the Moon does exercise an influence upon our atmosphere sufficient to produce tides similar to those in the ocean, yet the effect is almost inappreciable, and cannot under any circumstances cause atmospheric disturbances, or changes in the weather. The idea of a lunar "change" having an influence upon the weather is too ridiculous to be entertained even for a moment, because the Moon is constantly undergoing a "change" in her phases, and consequently, the weather ought to be as much influenced by this orb at one time as at another, but such is not observed to be the case.

The writer has investigated this subject and given it considerable attention for many years, but after repeated and long-continued observation he has arrived at the conclusion that no dependence can be placed upon the so-called "moon-signs," and that the Moon has no influence whatever upon our weather changes. The Moon's appearance goes through such marked changes each month that it would be very natural to attribute weather changes to these, and in this way most of the familiar old proverbs and superstitions current among the people have doubtless originated. The vicissitudes of the weather which have been supposed to follow the course of the lunar phases might be imagined, if they could be shown to have any reality, to be produced by atmospheric tides or currents arising from the Moon's attraction, like the tides of the ocean. It has been shown however, that there are no grounds whatever, either in theory or observation, for imputing to the Moon any meteorological influence, and that, as a matter of fact, there is no such accordance or correspondence between the lunar phases and changes in the weather. The famous Dr. Lardner, in an excellent and instructive article on "Lunar Influences," in which the subject is exhaustively and scientifically discussed, says: "In conclusion then, it appears that of all the various influences popularly supposed to be exerted by the Moon, few have any foundation in fact."

Diligent inquiry at one time as to the popular belief regarding the Moon's influence upon the weather brought out the view, more persistent than any other, that more rain will occur at the new than at the full Moon. A singular fact is that in Connecticut, and on Long Island Sound, there does seem to be such a law, but it does not hold in the interior of the country, and a test on the Pacific coast showed, if anything, exactly the opposite. At London, where observations have been made for more than a century, a careful computation for the whole period has shown no effect whatever. But the question naturally arises, if the

Moon can raise a tide of 60 feet in the ocean, why may it not raise a tide in the extremely tenuous air 800 times lighter than water, or a tide of about 48,000 feet, and if so, it is plain that such a commotion would affect our weather to a great extent. We must consider, however, that the ocean tide of 60 feet (the highest in the world) is produced only in the Bay of Fundy, and is due to the configuration of the Atlantic coast. In the open Pacific the tide is only a little over one foot. Most careful observations of lunar atmospheric tide have been made at St. Helena, in mid-ocean, and have shown a tide a little more than .001 of an inch by the change of height in the mercury of a barometer. Since any ordinary weather changes affect the pressure a thousand times as much, we can see how extremely insignificant the Moon's total effect must be; and as a recent writer has well remarked, "If we reflect that the Moon is dead and does not have any air even upon it, that it always shows the same face to the Earth, that its changes are simply due to changes in its position as respects the Earth and Sun, and that its varying appearances are all borrowed, we see how absurd the notion is that the Moon does influence the weather."

As the air is material, it should obey the Moon's attraction as well as the water of the seas and oceans. But the air flows in no narrowing channels or estuaries like those which condense the oceanic tide, and whatever wave it has must be compared with the lowest tide-wave in the open sea. The only evidence of an aerial tide will be derived from the varied pressure of the air, as indicated by the barometer; and the late Professor Peabody, in his "Elements of Astronomy," says: "The tide exists only to restore the balance of pressure which has been disturbed by an external attraction. The longer column of air under the Moon at high tide should not press more heavily than the shorter column at low tide, because it is precisely the lifting power of the Moon which causes any difference in height." An opinion prevails to some extent that moonlight disperses clouds, and sailors say, "The Moon eats the clouds." This opinion may be defended as the full Moon reflects a little solar heat, which may have a slight effect to expand vapor and scatter the clouds. But all scientific investigation indicates that the Moon has no influence on the weather, and that no forecast can be made by it. The traditions which teach the time of the Moon in which to sow, to plant, to kill pork, to cut timber, etc., are all too absurd to be refuted in this intelligent age of the world.

Observations continued during a period of 28 years, in and

near Munich, in Germany, gave the number of rainy days in the waxing, to the number in the waning, Moon, as 845 is to 696, or as 6 is to 5, nearly, which would indicate that it rains oftenest in the first half of the month, and similar results were obtained at Paris. Observations made for 10 years at Montpellier, in the south of France, found 9 rainy days in the waxing Moon to 11 in the waning Moon, a result opposite that found at Munich, only about 300 miles away. The results in either case indicate coincidences, not consequences, and more proof is needed before it can be admitted that the Moon influences the amount of rain. Professor C. A. Young, in his "Lessons in Astronomy," rightly remarks: "The most important effect produced upon the Earth by the Moon is the generation of the tides in co-operation with the Sun. There are also certain well-ascertained disturbances of the terrestrial magnetism connected with the approach and recession of the Moon in its oval orbit; and this ends the chapter of proved lunar influences. The multitude of current beliefs as to the controlling influence of the Moon's phases and changes upon the weather and the various conditions of life are mostly unfounded. It is quite certain that if the Moon has any influence at all of the sort imagined, it is extremely slight; so slight that it has not yet been demonstrated, though numerous investigations have been made expressly for the purpose of detecting it, but different workers continually come to contradictory results."

The evidence we have presented above ought to be conclusive, and should convince the most credulous persons that no dependence can be placed upon the so-called "moon-signs," and that our satellite has no influence whatever upon changes in the weather. It will be seen from the extracts quoted that there is a general concordance of opinion among the leading writers upon the subject, and we have presented their views in order to indicate the light in which the question is regarded by recognized authorities. But one fact upon which most astronomers agree, and which seems to be established by careful observation, is that the full Moon scatters or dissolves the clouds and produces a clear sky. There is a common saying that "The full Moon has power to drive away clouds," and some computations seem to bear out this idea. If any one will look to the east as the rising full Moon shines through the clouds, he will usually see the clouds disappear. There is a natural explanation for this, however, and it does not depend upon the Moon, as commonly supposed. Professor H. A. Hazen, of the United States Weather

Bureau, in a recent magazine article, thus explains the phenomenon: "A long series of observations has shown a diurnal range in cloudiness with a minimum point, or time of least clouds, from 6 to 9 P. M.; hence we see that, as the full Moon rises and advances in the sky during this period, there will often appear a diminution of clouds. The evidence is cumulative and overwhelming that no weather changes can be attributed to the Moon."

We must see the weight of evidence in opposition to the belief that the Moon governs or influences our weather changes, and other writers equally eminent have added their testimony to that above mentioned. Professor John Westwood Oliver, the famous meteorologist, in a very instructive article on "The Moon and the Weather," published in Longman's Magazine, thoroughly dispels the popular notions regarding the Moon, and plainly demonstrates the fallacy of the beliefs as to its influence on the Earth and the weather. The only influence that can properly be attributed to the Moon, which is generally recognized by astronomers, and will be evident to every student of the subject, is reduced to the fact and comprehended in the statement that, being our nearest celestial neighbor and equal in apparent size to the Sun, her mild splendor dissipates the shades of night, while her attractive power sensibly affects the motions of the Earth, and sways the tides of the ocean.

BATTLE CREEK, Mich.

THE MILKY WAY AS IT APPEARS TO OBSERVERS OF THE AUTUMN HEAVENS.

ROSE O'HALLORAN.

The clear evenings of October especially invite attention to that "broad and ample road whose dust is gold and pavement stars," for at this season its most conspicuous parts span the firmament, emerging from the northeastern mists and disappearing in those of the southwest. Despite the alluring testimony of poetic fanciers, the aspect of the galaxy or Milky Way is more silvery than golden. A cirrus cloud or a smoke wreath on a background of dark sky may also resemble this vastest of visible formations, for such are the drawbacks of mortal vision that the greatest and the least may look alike. Though for many thousands of years mankind has viewed it with more or less interest, so far it has eluded exact delineation, even excellent draughts-

men failing to give concurrent evidence as to detail. Irregularity of outline, varied structure and fine gradations of light are always subject to the personality of the observer. Within the last few years an effort has been made to obtain a large number of careful drawings, which will give additional evidence on the unsettled points, for drawings alone can give due effect to its visible complexities, as the photographic plate, though invaluable in other respects, overdepicts and underdepicts commingled degrees of luminosity. Even Professor Burckhalter's successful appliance for coronal inequalities would be baffled by the unsymmetrical glows of the galaxy.

To see it in full luster twilight must be completely passed, the Moon absent and the atmosphere exceptionally clear. Like a wandering stream, its width varies considerably. In viewing the tract extending toward the zenith from Cassiopeia and Cynus it is not surprising that Pythagoras and other sages of antiquity recognized its stellar nature, as its studded aspect is strongly suggestive of myriads of unseen starpoints. Two small nonluminous spaces like islets in a river may be traced in the northern part of Cygnus, which is also the starting point of other complexities. Here begins the marvelous division into two separate strips, prolonged lengthwise through the constellations of Sagitta and Aquila. An unsurpassed massing of nebulosity commences the northwesterly branch, which decreases in luster and dims to invisibility in Ophiuchus; while the more southerly branch continues its course athwart the heavens to where the Archer bends his bow in the southwest.

Professor Barnard's admirable photographs of this complex curve have revealed a network of nebulosity before unseen and strange structural tendencies in different degrees of condensation. The astrographic charts, a series of international sky pictures soon to be completed, will also give much detail as to the stelliferous pavement and its glittering dust. With declining glimmer scattering considerably toward Scorpio it passes below our horizon, where its brilliancy and the dark tract known as "coal-sack" have long been the wonder of travelers.

When within 20 degrees of the South Pole of the heavens it curves northward, appearing in our skies again in Argo. The greatest marvel of this section is the narrow but complete rift crosswise, as total a separation of the milky stream as the Scriptural dividing of the Red Sea in the days of Pharaoh. This less conspicuous half of the starry zone arches above us in the autumn and winter months from the southeast to Cassiopeia,

thence northwest and to within 23 degrees of the Pole star. The indications of globular distribution in some parts, and the inexplicable sunderings of this vast formation, numbering tens of millions of stars, at various and incredible distances, waken appalling fancies as to cosmic possibilities. Some astronomers think that there are as many dark bodies as bright ones in the universe. We know that there are many in the solar system, and some variable stars, spectroscopic binaries and double star orbits indicate their presence in interstellar space, but there is no clew as to size or number. To form a clear idea of the position of the galaxy relative to the solar system and to the visible universe we may imagine the Earth to be perfectly transparent and sunlight extinguished, so that on looking downward we could see the hidden half of the starry sphere, within which our world seems to be inclosed, having a standpoint near the center.

It will be interesting for the time being to ignore the seeming rotation of the heavens, the celestial poles, the equator and Sun's path which are earthly effects and appear to be independent of the trend of cosmical matter. The Milky Way would then be seen passing around the sphere both above and beneath, and dividing it into about equal parts. The word girdle or belt, so often used in describing it, is misleading from our standpoint as it conveys an impression of an outside view, which may exist, but is forever beyond mortal ken. Our view is from within. The width of this luminous zone is about one-tenth its seeming diameter which corresponds with the diameters of the areas of sky which it separates. Though there are a few fragmentary distributions of similar luster throughout the sphere, the extent, continuity and central position of the galaxy have the deepest significance. Its stellar nature shows that an immense majority of the stars discernible in a telescope are distributed in a portion of space between two planes described by the borders of the galactic zone. The phrase "a round, flat disk," is often used to explain the aspect of the starry aggregation as seen from the outside. Obedient to some mighty and irresistible law, this marshaling of sidereal myriads is a cosmical fact written around the visible universe. Within these planes is also the allotted place of the Sun and its planets including the Earth, for our great light-giver is but the nearest of the components of the Milky Way.

This supposed view of the entire galaxy through a transparent earth easily suggests the inquiries: Is our place then the center of a stellar ring? At what distance is the encircling throng?

Does the starry aggregation extend outward to infinity?

There is some evidence and much probability that the central area is not a reservation for the solar system alone, but is also strewn with orbs less remote than the surrounding legions.

The greater brilliancy of the Milky Way near the Centaur and the Southern Cross may not be inherent, as such increase of luster would be the result, if our position were not exactly central, but somewhat nearer to that curve of the luminous circle. As to its distance, the components are largely orbs of tenth to fourteenth magnitude, and though small stars are not always the most distant, it is considered that, in the main, their apparently small size is evidence of remoteness. The star guaging of the immortal Herschel, though fruitful in results, failed to answer the third inquiry. As there is no evidence that the orbs of heaven are scattered at equal distances from each other, a crowded field of view does not necessarily tell of an extension in space of that section of the sidereal system, and may equally well signify compactness as to distribution; while the impenetrable nebulosity that confronts a giant lens in some deeper depths is also mystifying, but hints of sublime possibilities as to extension. The true dimensions and form out beyond the perspective ring, but ringwise, have thus as yet defied theory.

The two immense segments of sky which are separated by this central condensation also yield undoubted proofs that the visible cosmos is not a chaotic assemblage of matter. In the star-guaging of Herschel and other observers it was found that in general a telescopic field of view in the Milky Way has more than double the number of stars seen in an equal space a few degrees beyond its borders, and thirty times as many as at the two points of the sky farthest from its plane, one in Coma Berenices and the other south of Cetus, this remarkable decrease being gradual.

An axis of infinite length and centrally perpendicular to the galactic circle would seem to touch the heavens in these constellations, which are known as the galactic polar regions. The few thousand stars visible to the naked eye are only slightly affected by this law of distribution. This would be the effect if the sidereal system had the form of a round flat disk, and that the larger stars as a class were the nearest; but a few cosmogonists consider that the sides of the system, where the thinning of the starry hosts is apparent, may have a globular or some other form. There also is found further evidence of distinctive arrangement.

While around in the stellar thoroughfare star clusters and

gaseous nebulæ abound, those luminous flecks that fail, from distance or some other cause, to disclose whether they are composed of stars or gas, are evidently allotted to a different place and a different function. Where the stars diminish in number, this class of nebulæ increase, and are strewn in thousands in the region of the galactic poles where stars are scarce.

The function of nebulæ in the transcendently slow process of cosmical change is open to many conjectures. Man in his fleeting hour can only grope for a few facts, leaving a future accumulation to weave the wondrous tale. The structure of the galaxy, visibly riven and bored, dense here and dim elsewhere, jagged in one part, smooth or rounded in another, suggests the sway of stupendous forces proceeding from either luminous or non-luminous matter.

PLANET NOTES FOR SEPTEMBER.

H. C. WILSON.

Mercury will be at greatest elongation, east from the Sun 26° 11′, on Sept. 24 and so will be evening star all of this month. It will be visible to the naked eye, in the west a half hour to an hour after sunset, during the latter half of the month. On Sept. 20 the planet will be close to the star α Virginis (Spica), so that on that evening there will be a good opportunity for comparing the brightness of the planet with that of the star. The brightness of Spica according to the Harvard Photometric System is 1.20^{m}.

Venus is morning star, and is getting too close to the Sun to be very conspicuous. The planet is on the farther side of its orbit from the Earth and is slowly approaching superior conjunction. Venus will be at perihelion Sept. 11.

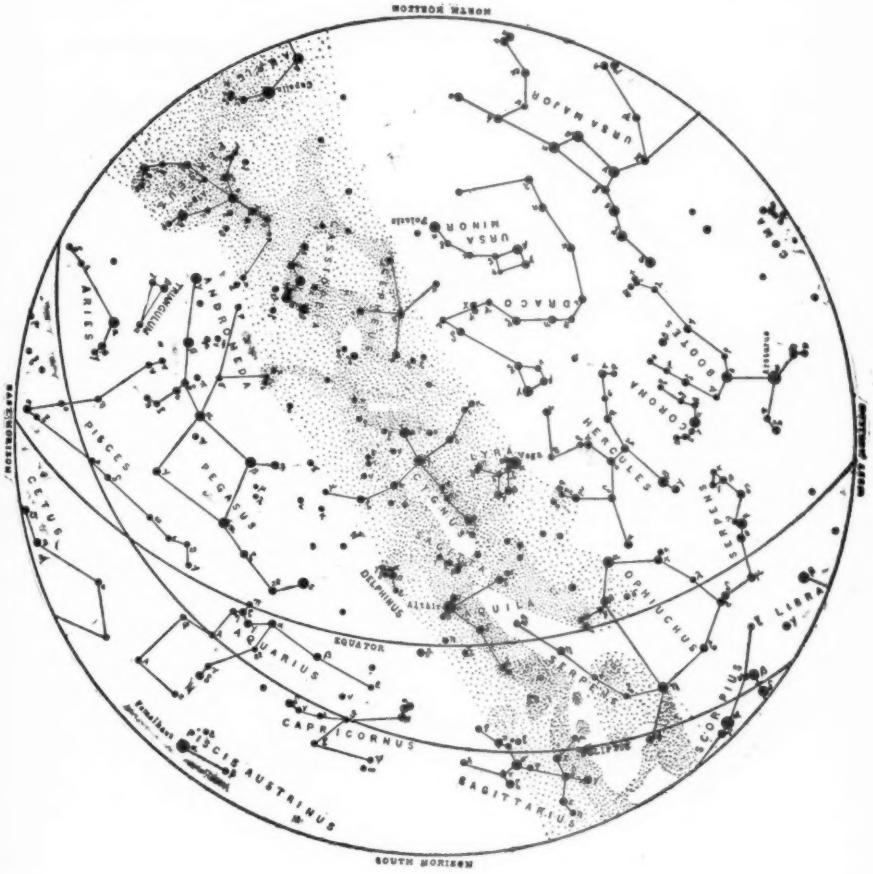
Mars is also morning planet, being near the meridian at nine o'clock in the morning. The planet's apparent diameter is yet very small, being only 4″.5 on Sept. 5, so that observations of its surface markings are very difficult. Mars and the Moon will be in conjunction Sept. 27 at 4^{h} P. M. Central Standard time.

Jupiter is brilliant now in the southeastern sky in the early evening and is a beautiful object in small telescopes. The low altitude of the planet prevents any very satisfactory study of its surface-markings with large telescopes, but with small instruments and low power the atmospheric disturbances are not so noticeable. The two principal belts of Jupiter and the satellites are visible under almost any conditions of seeing. Jupiter and the Moon will be in conjunction on the morning of Sept. 14. the Moon passing 6° to the north of Jupiter.

Saturn is also an early evening planet, near the meridian at nine o'clock in the constellation Sagittarius, and about eighteen degrees west of Jupiter. It is recognized at once by its golden color and its brilliancy, which is next to that of Jupiter in that part of the heavens. The rings of Saturn are turned so that their plane makes an angle of 23° to the line of sight, and the details of their structure may be well seen whenever the seeing is good. Unfortunately the

altitude of the planet is such in this latitude that moments of good seeing are few and far between. Saturn will be stationary Sept. 26 and after that time will move slowly eastward. The Moon and Saturn will be in conjunction Sept. 12.

Uranus will be at quadrature, 90° east from the Sun, Sept. 10, and is to be found early in the evening, with the aid of a telescope, among the faint stars at



THE CONSTELLATIONS AT 9 P. M. SEPTEMBER 1, 1902.

the foot of Ophiuchus, between Scorpio and Sagittarius, and 5° southwest of the star θ Ophiuchi.

Neptune will be at quadrature, 90° west from the Sun Sept. 27, and so is visible in the early morning. It is to be found, with the aid of a telescope, near the star μ Geminorum.

The Moon.

	Phases.		Rises. (Central Standard Time at Northfield Local Time 13m less.)		Sets.	
			h	m	h	m
Sept.	1	New Moon	4	57 A. M.	6	19 P. M.
	9	First Quarter	1	17 P. M.	10	55 "
	17-18	Full Moon	6	10 "	6	52 "
	23-24	Last Quarter.	10	18 "	1	30 A. M.

Occultations Visible at Washington.

Date. 1902.	Star's Name.	Magnitude.	IMMERSION. Washington M.T. h	m	Angle f'm N pt. °	EMERSION. Washington M. T. h	m	Angle f'm N pt. °	Duration. h	m
Sept. 6	5 Librae	6.6	10	11	173	10	24	201	0	13
7	ζ^2 Librae	7.0	6	08	122	7	26	255	1	18
15	B.A.C. 7717	6.9	4	58	46	5	54	281	0	56
24	26 Geminorum	5.0	11	24	56	12	08	302	0	44
26	A^2 Cancri	5.8	15	32	144	16	20	239	0	48

Phenomena of Jupiter's Satellites.

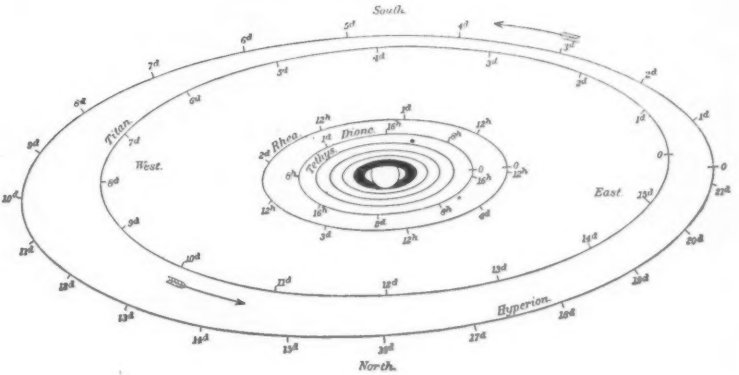
Central Standard Time.

	h	m				h	m		
Sept. 5	8	11 P. M.	II	Oc. Dis.	Sept. 17	8	50 P. M.	I	Tr. In.
6	12	35 A. M.	II	Ec. Re.		9	49 "	I	Sh. In.
	8	50 P. M.	III	Sh. Eg.		11	11 "	I	Tr. Eg.
	10	42 "	IV	Tr. In.		12	09 "	I	Sh. Eg.
7	6	11 "	II	Tr. Eg.	18	9	27 "	I	Ec. Re.
	7	46 "	II	Sh. Eg.	19	6	38 "	I	Sh. Eg.
9	12	34 A. M.	I	Tr. In.	20	9	00 "	III	Tr. In.
	1	25 "	I	Sh. In.	21	7	58 "	II	Tr. In.
	9	55 P. M.	I	Oc. Dis.		10	04 "	II	Sh. In.
10	1	03 A. M.	I	Ec. Re.		10	54 "	II	Tr. Eg.
	7	03 P. M.	I	Tr. In.	23	7	06 "	IV	Tr. Eg.
	7	53 "	I	Sh. In.		7	07 "	II	Ec. Re.
	9	23 "	I	Tr. Eg.	24	6	57 "	III	Ec. Re.
	10	14 "	I	Sh. Eg.		10	39 "	I	Tr. In.
11	7	32 "	I	Ec. Re.		11	44 "	I	Sh. In.
12	10	30 "	II	Oc. Dis.	25	11	23 "	I	Ec. Re.
	9	07 "	III	Sh. In.	26	6	13 "	I	Sh. In.
	9	10 "	III	Tr. Eg.		7	27 "	I	Tr. Eg.
14	7	27 "	II	Sh. In.		8	33 "	I	Sh. Eg.
	8	32 "	II	Tr. Eg.	27	5	31 "	I	Ec. Re.
	10	23 "	II	Sh. Eg.	28	10	2 "	II	Tr. In.
15	6	53 "	IV	Ec. Re.	30	9	44 "	II	Ec. Re.
16	11	43 "	I	Oc. Dis.					

NOTE.—In. denotes ingress; Eg., egress; Dis., disappearance; Re., reappearance; Ec., eclipse; Oc., occultation; Tr., transit of the satellite; Sh., transit of the shadow.

U Persei a Comparison Star for Eros.—In *A. N.* 3794 Mr. Arthur R. Hinks calls attention to the fact that the star BD+ 54°.431 (1^h 52^m 56^s, + 54° 20′ for 1900.0), which was included in the first list of reference stars for the reduction of photographs of Eros, is the variable U Persei. It was photographically faint during the days 1900, Nov. 9-14 when the planet was near it, and probably will not be found on many of the photographs. On the photographs taken at Northfield Nov. 10, 13 and 14 it was noted as approximately 11^m.

The Satellites of Saturn.



APPARENT ORBITS OF THE SEVEN INNER SATELLITES OF SATURN, AT OPPOSITION IN 1902 AS SEEN IN AN INVERTING TELESCOPE.

I. MIMAS.

Period 0^d $22^h.6$

		h		
Sept.	5	7.5	P. M.	W
	6	6.1	"	W
	11	10.6	"	E
	12	9.2	"	E
	13	7.8	"	E
	14	6.4	"	E
	19	10.9	"	W
	20	9.5	"	W
	21	8.1	"	W
	22	6.7	"	W
	23	5.3	"	W
	28	9.8	"	E
	29	8.4	"	E
	30	7.0	"	E

II. ENCELADUS.

Period 1^d $8^h.9$

Sept.	5	12.3	A. M.	E
	6	9.2	"	E
	7	6.1	P. M.	E
	9	3.0	A. M.	E
	10	11.9	"	E
	11	8.7	P. M.	E
	13	5.6	A. M.	E
	14	2.5	P. M.	E
	15	11.4	"	E
	17	8.3	A. M.	E
	18	5.2	P. M.	E
	20	2.1	A. M.	E
	21	10.0	"	E
	22	7.8	P. M.	E
	24	4.7	A. M.	E
	25	1.6	P. M.	E

II. ENCELADUS.—Con.

Period 1^d $8^h.9$

		h		
Sept.	26	10.5	P. M.	E
	27	7.4	A. M.	E
	29	4.3	P. M.	E
	31	1.1	A. M.	E

III. TETHYS.

Period 1^d $21^h.3$

Sept.	5	7.2	A. M.	E
	7	4.5	"	E
	9	1.8	"	E
	10	11.1	P. M.	E
	12	8.4	"	E
	14	5.7	"	E
	16	3.0	"	E
	18	0.3	"	E
	20	9.7	A. M.	E
	22	7.0	"	E
	24	4.3	"	E
	26	1.6	"	E
	27	10.9	P. M.	E
	29	8.2	"	E

IV. DIONE.

Period 2^d $17^h.7$

Sept.	5	8.1	P. M.	E
	8	1.8	"	E
	11	7.5	A. M.	E
	14	1.2	"	E
	16	6.9	P. M.	E
	19	0.5	"	E
	22	6.2	A. M.	E
	24	11.9	P. M.	E
	27	5.6	"	E
	30	11.3	A. M.	E

V. RHEA.

Period 4^d $12^h.5$

Sept.	6	3.0	P. M.	E
	11	3.3	A. M.	E
	15	3.7	P. M.	E
	20	4.1	A. M.	E
	24	4.6	P. M.	E
	29	5.0	A. M.	E

VI. TITAN.

Period 15^d $23^h.3$

Sept.	4	9.7	P. M.	E
	8	12.0	midn.	I
	12	12.0	"	W
	16	8.7	P. M.	S
	20	8.0	"	E
	24	10.3	"	I
	28	10.4	"	W

VII. HYPERION.

Period 21^d $7^h.6$

Sept.	1.7	I
	7.8	W
	13.6	S
	18.2	E
	22.9	I
	29.0	W

VIII. IAPETUS.

Period 79^d $22^h.1$

Sept.	8.7	W
	28.9	S
Oct.	18.7	E

COMET AND ASTEROID NOTES.

Search Ephemeris for Comet 1895 II (Swift).—In *A. N.* 3794 Mr. L. Schulhof gives a search ephemeris for Swift's Comet II 1895, extending from June 25 to Nov. 12, 1902. The comet was extremely faint in 1895 and it is quite doubtful whether, under less favorable circumstances, it will be found at this return. The region of the comet's position was photographed at Goodsell Observatory on the nights of July 1 and 7, with exposures of 60^m and 80^m respectively, with the 6-inch and 2½-inch cameras, but no trace of the comet is shown. Mr. Schulhof estimates the uncertainty of the time of perihelion passage at ± 3 days which would give the comet a possible range of from 1° to 2° in right ascension and from 10′ to 20′ in declination on either side of the ephemeris positions.

ELEMENTS OF COMET 1895 II.

Epoch 1902 Oct. 1.0 Paris M. T.

$M = 354°\ 53'\ 43''$
$\pi = 338\ 15\ 49$ } 1902.0
$\Omega = 170\ 16\ 56$ }
$i = 3\ 00\ 43$ }

$\phi = 40°\ 36'\ 56''$
$\mu = 490''.905$
$\log a = 0.572673$

EPHEMERIS FOR MIDNIGHT AT PARIS.

1902.	R. A.	Decl.	log Δ	1 : $r^2\Delta^2$
	h m s	° ′		
Sept. 1	16 18 55	−17 56.1	0.0770	
3	22 44	18 9.8		
5	26 41	18 23.5	0.0793	0.307
7	30 48	18 37.2		
9	35 4	18 50.9	0.0813	
11	39 29	19 4.4		
13	44 3	19 17.7	0.0832	0.319
15	48 46	19 30.8		
17	53 37	19 43.6	0.0850	
19	16 58 38	19 56.1		
21	17 3 47	20 8.3	0.0866	0.332
23	9 4	20 20.0		
25	14 30	20 31.1	0.0880	
27	20 5	20 41.7		
29	25 48	20 51.8	0.0894	0.345
Oct. 1	31 39	21 1.2		
3	37 38	21 9.8	0.0908	
5	43 46	21 17.7		
7	50 1	21 24.8	0.0921	0.355
9	17 56 24	21 30.9		
11	18 2 54	21 36.1	0.0935	
13	9 31	21 40.3		
15	16 14	21 43.4	0.0950	0.363
17	23 5	21 45.4		
19	30 1	21 46.3	0.0967	
21	37 4	21 46.0		
23	44 13	21 44.4	0.0985	0.365
25	51 27	21 41.5		
27	18 58 46	21 37.2	0.1006	
29	19 6 10	21 31.5		
31	19 13 38	−21 24.5	0.1030	0.364

Elements of Asteroid 1901 GT.—In *A. N.* 3805 Mr. M. Ebell gives two sets of elements of this planet. It was found by Dr. Wolf at Heidelberg on Sept. 19, 1901 and was followed only until September 24. On a photograph

taken Dec. 5, 1901 at Heidelberg two asteroids were found, one of which was thought to be GT and the other, regarded as new, was called 1901 HM. Now Mr. Ebell thinks the one named HM is really GT and the other is very probably (156) Xanthippe. The elements which best satisfy the observations of GT are:

EPOCH 1901, SEPT. 20.0 BERLIN, M. T.

$M = 108°\ 15'\ 08''.1$
$\omega = 331\ 48\ 19\ .9$
$\Omega = 242\ 40\ 39\ .2$ 1901.0
$i = 9\ 39\ 24\ .8$

$\phi = 11°\ 25'\ 18''.8$
$\mu = 788''.390$
$\log a = 0.435511$

New Asteroids.—The following have been added to the list of newly discovered objects during the summer:

			Local M. T.	R. A.	Decl.	Mag.
			h m	h m	° ′	
1802 HX	Wolf,	Heidelberg	April 29 10 45.2	14 45.6	+ 4 46	12.5
HY	"	"	May 7 12 45.2	15 13.2	−13 19	12.5
HZ	Carnera	"	7 10 41.0	15 06.7	− 5 54	12
JA	Wolf	"	7 12 45.2	15 19.5	−17 25	13
JB	Carnera	"	11 11 01.9	16 17.5	− 7 48	11.5
1900 JC	Lais	Rome	Oct. 28 11 25.8	3 39.2	+24 50	12
1902 JD	Wolf	Heidelberg	June 3 11 37.4	15 58	−23.1	11.5
1899 JF	Pulfrich	"	9 11 49.6	17 14	−22 44	12.5
1902 JG	Wolf	"	26 10 59.4	15 37.2	−13 46	——
JH	"	"	26 10 59.4	15 36.0	−12 04	——
JJ	Carnera	"	27 11 29.8	15 21.3	− 8 42	12
JK	Wolf	"	July 6 10 50.9	18 25.7	− 7 48	12.5
JL	Carnera	"	9 12 13.7	20 25.9	−19 58	12

1899 JF was discovered with the aid of a stereo-comparator by Dr. C. Pulfrich of Jena, upon two plates exposed June 9 and 10, 1899 by Dr. Wolf of Heidelberg.

1902 JH is found by Mr. Berberich to be identical with 1902 JB. Dr. Wolf suggests that 1902 JK is probably (470) Kilia.

Elements of Asteroid (443) Photographica.—In *A. N.* 3805 Mr. Anton Thraen gives new elements of the planet (443) Photographica based upon observations in 1899 and 1902. The elements for 1902 are:

EPOCH 1902, JAN. 14.0 BERLIN M. T.

$M = 309°\ 25'\ 02''.3$
$\omega = 344\ 44\ 42\ .3$
$\Omega = 175\ 01\ 40\ .9$ 1900.0
$i = 4\ 13\ 12\ .4$

$\phi = 2°\ 18'\ 20''.1$
$\mu = 1075''.8837$
$\log a = 0.345494$

Elements of Planet (371) Bohemia.—In *A. N.* 3799 Mr. H. Mader gives the following elements of the Asteroid (371), depending upon observations in the years 1893, '94, '96, '98 and '99:

EPOCH AND OSCULATION, 1900, JUNE 13.0, BERLIN.

$M = 222°\ 16'\ 16''.70$
$\omega = 339\ 48\ 04\ .62$
$\Omega = 284\ 08\ 39\ .63$ 1900.0
$i = 7\ 23\ 09\ .27$

$\phi = 3°\ 29'\ 00''.98$
$\mu = 787''.90865$
$\log a = 0.4356872$

The planet was at opposition July 20, 1902.

Elements of Planet (475) Ocllo.—In *A. N.* 3800 Dr. H. Kreutz gives new elements of the planet (475) which was discovered by Dr. DeLisle Stewart upon photographs taken with the 24-inch Bruce telescope at Arequipa, Peru.

EPOCH 1901, SEPT. 30.5, BERLIN, M. T.

$M = 357°\ 54'.88$
$\omega = 301\ 37.97$
$\Omega = 35\ 48.05$ 1900.0
$i = 18\ 38.17$

$\phi = 22°\ 19'.52$
$\mu = 852''.660$
$\log a = 0.41282$

Dr. Stewart has chosen for the planet the name of the first queen of the Incas, Ocllo, traditional Daughter of the Sun.

Rediscovery of Eros.—Eros was visually rediscovered by Dr. Chas. J. Ling with the twenty-inch refractor of the Chamberlin Observatory at 3:15 A. M., on Aug. 2. Accurate measures of its position were precluded by advancing twilight and haze. The planet was judged to be not fainter than magnitude 12, and its right ascension was estimated to be 15 or 20 seconds less than that given by an ephemeris. Miss Mary Clark Traylor had computed the ephemeris from the latest one of the orbits given by Millosevich in *A. N.* 3741. This orbit was osculating for Mar. 20.5, 1901, and the perturbations since that date were not computed by Miss Traylor, as her ephemeris is intended for finding purposes only.

On the morning of Aug. 7 Dr. Ling made an accurate observation, a preliminary reduction of which shows that the planet's right ascension is about 15 seconds less than that interpolated from the ephemeris, while the discrepancy in declination is but a fraction of a minute. The magnitude was again estimated as not lower than 12; a similar estimate was made on Aug. 6, when an accident caused the loss of the observations for position. Still another estimate on Aug. 12 agreed with the preceding.

In view of the variability of Eros it is interesting to note that Dr. Ling's estimates of magnitude make the planet more than one magnitude brighter than would be expected from the Harvard *Circular*, No. 61, and a fraction of a magnitude brighter than values computed from data given in the *Berliner Jahrbuch*. Since Dr. Ling's work was done when Eros was rather low in the east, and when the sky was lighted up somewhat by the approaching dawn, it seems likely that he did not overestimate the planet's brightness, and therefore that photometric measures may well be made as soon as possible at those observatories which are equipped for such work. On two mornings the planet did not fade from sight until four o'clock.

Eros is now moving eastward nearly as fast as the Sun, and will move southward for several months, so that it will not be very favorably placed for observations in the northern hemisphere.

The position on Aug. 11, at $15^h\ 25^m\ 19^s$ Univ. Park, M. T. was

R. A. $5^h\ 36^m\ 35^s.03$
Decl. $+\ 31°\ 56'\ 17''.7$.

VARIABLE STARS.

The Minimum of Mira, Dec. 1901.—In *A. N.* 3795 Mr. A. A. Nijland of the Observatory at Utrecht gives the results of his observations of Mira (o Ceti) from August 11,1901 to Mar. 5 1902. A curve drawn on the platted observations indicates a minimum magnitude of 8.75, on the Harvard Photometric system, about Dec. 29,1901.

Minima of Variable Stars of the Algol Type.

[Greenwich Mean Time beginning with midnight. The hours greater than 12 are those of the afternoon. To obtain Eastern Standard time subtract 5 hours; for Central Standard subtract 6 hours, etc.]

U Cephei.

	d	h
Sept.	2	1
	4	13
	7	1
	9	13
	12	1
	14	12
	17	0
	19	12
	22	0
	24	12
	27	0
	29	11

Algol.

Sept.	3	20
	6	16
	9	13
	12	10
	15	7
	18	4
	21	1
	23	22
	26	18
	29	15

λ Tauri.

Sept.	3	21
	7	20
	11	19
	15	18
	19	16
	23	15
	27	14

R Canis Majoris

Sept.	5	3
	6	6
	7	10
	8	13
	9	16
	10	19
	11	23
	13	2
	14	5
	15	8
	16	12
	17	15

R Can. Maj. Cont.

	d	h
Sept.	18	18
	19	21
	21	1
	22	4
	23	7
	24	10
	25	14
	26	17
	27	20
	29	0
	30	3

S Cancri.

Sept.	3	6
	12	18
	22	5

S Antliæ.

Period $7^h\ 46^m.8$

Sept.	4	10
	5	9
	6	9
	7	8
	8	7
	9	7
	10	6
	11	5
	12	5
	13	4
	14	3
	15	3
	16	2
	17	1
	18	1
	19	0
	19	23
	20	23
	21	22
	22	21
	23	21
	24	20
	25	19
	26	19
	27	18
	28	17
	29	17
	30	16

δ Libræ. Con.

	d	h
Sept.	5	19
	8	3
	10	11
	12	19
	15	3
	17	11
	19	18
	22	2
	24	10
	26	18
	29	2

U Coronæ.

Sept.	2	18
	6	5
	9	15
	13	2
	16	13
	20	0
	23	11
	26	22
	30	9

U Ophiuchi.

Sept.	5	13
	6	9
	7	5
	8	1
	8	21
	9	18
	10	14
	11	10
	12	6
	13	2
	13	22
	14	18
	15	14
	16	11
	17	7
	18	3
	18	23
	19	19
	20	15
	21	11
	22	8
	23	4
	24	0
	24	20

U Ophiuchi Con.

	d	h
Sept.	25	16
	26	12
	27	8
	28	4
	29	1
	29	21
	30	17

RX Herculis.

Sept.	4	21
	5	18
	6	16
	7	13
	8	10
	9	8
	10	5
	11	2
	12	0
	12	21
	13	19
	14	16
	15	13
	16	11
	17	8
	18	5
	19	3
	20	0
	20	21
	21	19
	22	16
	23	13
	24	11
	25	8
	26	5
	27	3
	28	0
	28	21
	29	19
	30	16

Z Herculis.

Sept.	2	13
	4	14
	6	13
	8	13
	10	12
	12	13
	14	12
	16	13

Z Hercu. Con.

	d	h
Sept.	18	12
	20	13
	22	12
	24	13
	26	12
	28	13
	30	12

SY (V^3) Cygni.

Sept.	3	12
	9	12
	15	12
	21	12
	27	12

SW (U^3) Cygni.

Sept.	6	9
	10	22
	15	12
	20	2
	24	16
	29	5

W Delphini.

Sept.	4	2
	8	22
	13	17
	18	13
	23	8
	28	3

Y Cygni.

Sept.	5	0
	6	8
	8	0
	9	8
	11	0
	12	8
	14	0
	15	8
	17	0
	18	8
	20	0
	21	8
	23	0
	24	8
	26	0
	27	8
	28	23
	30	7

Variable Stars of Short Period not of the Algol Type.

	Minimum.		Maximum.	
		h		h
η Aquilæ	Sept. 2	5	Sept. 4	11
T Vulpeculæ	3	2	4	11
S Sagittæ	4	7	7	17
β Lyræ	4	7	7	9
ζ Geminorum	4	7	9	7
W Geminorum	4	11	7	1
U Sagittarii	5	9	8	8
U Aquilæ	5	10	7	14
Y Sagittarii	5	21	7	16
δ Cephei	5	22	7	13
Y Ophiuchi	6	2	12	7
X Sagittarii	6	5	9	2
W Virginis	6	8	14	12
W Sagittarii	7	2	10	2
T Vulpeculæ	7	13	8	22
T Monocerotis	8	2	16	0
X Cygni	8	11	15	6
η Aquilæ	9	10	11	16
β Lyræ	10	18	14	3
δ Cephei	11	7	12	22
Y Sagittarii	11	16	13	11
T Vulpeculæ	11	23	13	8
U Sagittarii	12	3	15	2
W Geminorum	12	5	14	20
U Aquilæ	12	10	14	14
S Sagittæ	12	16	16	2
X Sagittarii	13	5	16	2
ζ Geminorum	14	11	19	11
W Sagittarii	15	10	18	10
T Vulpeculæ	16	10	17	19
η Aquilæ	16	14	18	20
δ Cephei	Sept. 16	16	Sept. 18	7
β Lyræ	17	5	20	7
Y Sagittarii	17	10	19	5
U Sagittarii	18	21	21	20
U Aquilæ	19	11	21	15
W Geminorum	19	22	22	13
X Sagittarii	20	5	23	2
T Vulpeculæ	20	20	22	5
S Sagittæ	21	1	24	11
δ Cephei	22	0	23	15
W Sagittarii	23	0	26	0
Y Sagittarii	23	5	25	0
Y Ophiuchi	23	5	29	10
W Virginis	23	14	31	18
β Lyræ	23	16	27	1
η Aquilæ	23	18	26	0
ζ Geminorum	24	15	29	15
X Cygni	24	20	31	15
T Vulpeculæ	25	7	26	16
U Sagittarii	25	15	28	14
U Aquilæ	26	11	28	15
X Sagittarii	27	6	30	3
δ Cephei	27	9	29	0
W Geminorum	27	16	30	7
Y Sagittarii	28	23	30	18
S Sagittæ	29	10	Oct. 2	20
T Vulpeculae	29	17	1	2
β Lyrae	30	3	3	5
W Sagittarii	30	14	3	14
η Aquilae	30	22	3	4

Maxima and Minima of Long Period Variables.

[Computed from Chandler's "Third Catalogue" by Misses Ida I. Watson and Helen M. Swartz of Vassar College Observatory.]

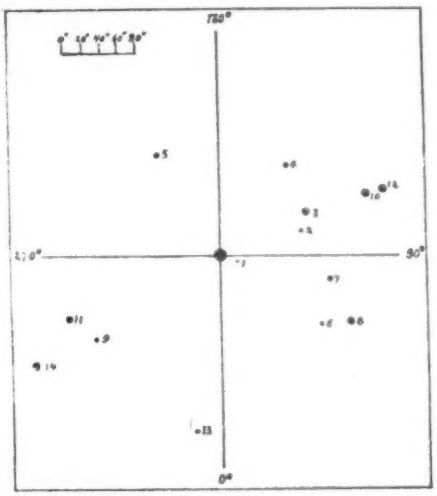
Maxima.			Minima.		
Date Sept.	No.	Star.	Date Sept.	No.	Star.
1	5617	U Librae	2	7609	T Cephei
3	2976	V Cancri	3	5338	U Bootis
4:	659	X Cassiopeae	4	782	R Arietis
5	2530	V Canis Minoris	7	6044	S Herculis
8	3477	R Leonis Minoris	9	893	U Ceti
9	8324	V Cassiopeae	12	7560	R Vulpeculae
14	7120	X Cygni	14	2946	R Cancri
19:	6943	T Sagittae	17	4511	T Ursae Majoris
20	466	U Piscium	17	6512	T Herculis
21	6921	S Sagittarii	18	7754	W Cygni
24	5583	X Librae	18	8068	S Lacertae
24	5831	S Scorpii	22	4492	Y Virginis
29	5761	Z Scorpii	28	5675	V Coronae
30:	1803	T Leporis	31	3994	S Leonis
30	2857	U Puppis			

Nova Persei.—In *A. N.* 3796 Professor E. E. Barnard give the results of a number of measures from Nova Persei to neighboring stars, made with the 40-inch Yerkes telescope. The following are the mean results, side by side with

similar results obtained by Professor Aitken with the 36-inch telescope of Lick Observatory:

	Barnard.				Aitken.			
Star	Mag.	P. A. °	Dist. ″	No. Nights.	Mag.	P. A. °	Dist. ″	No. Nights.
1	14.7	66.69	19.44	5				
2	13.5	107.42	90.67	7	14.5	108.0	91.37	2
3	12.6	116.35	102.61	7	13.5	116.8	102.65	3
4	13.6	142.77	120.57	4	15.5	142.7	121.34	1
5	12.9	211.14	124.37	6	13.0	211.1	124.62	3
6	13.9	56.79	132.02	4				
7	13.5	77.92	132.35	6				
8	12.5	63.10	158.45	8	13.0	63.2	158.61	5
9	13.1	303.50	164.78	6				
10	12.4	114.51	169.59	7	13.2	114.45	170.19	4
11	12.9	292.95	181.59	7				
12	13.6	113 00	190.54	5				
13	14.0	352.48	193.07	3	13.8	352.48	193.14	4
14	11.7	300.62	236.47	5	12.5	300.45	236.12	4

The epochs of Professor Barnard's measures average about 1902.0 while those of Professor Aitken are near 1901.2. The accompanying chart shows the positions of these stars relative to the Nova.



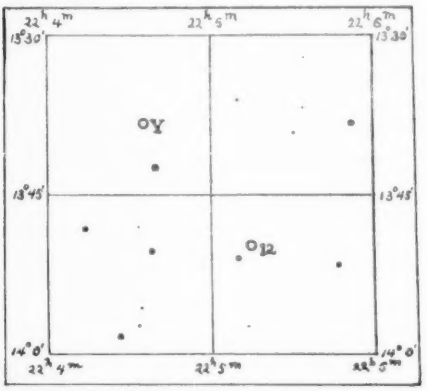
STARS IN THE VICINITY OF NOVA PERSEI.

Professor Barnard also gives a series of estimates of the brightness of the Nova extending to April 15, 1902, when the magnitude was 9.0.

New Variable Stars 10, 11 and 12, 1902.—No. 10.1902 Cygni was discovered by Mrs. Fleming upon photographs taken at Harvard College Observatory. It was noticed while a comparison of two plates, taken April 3, 1902 and March 7, 1900, was being made for the purpose of determining whether Brook's new comet, *a* 1902, had been photographed previous to its discovery April 14. In the great collection of astronomical photographs at that Observatory 388

were found which showed the new variable at its full brightness and 19 which showed it fainter. These were scattered over the years from 1891 to 1902, so that data were immediately at hand for the study of its character.

The star is found to be of the Algol type with a period of 31.304 days. It "retains its full brightness for 28 days, its photographic magnitude at maximum being 8.9. About a day before the minimum it begins to diminish, attaining the magnitude 9.0 at $1^d.05$ before minimum, 9.5 at $0^d.94$, 10.0 at $0^d.84$, 10.5 at $0^d.71$, 11.0 at $0^d.58$ and 11.5 at $0^d.43$. The light remains nearly constant for more than half a day, with the minimum magnitude 11.6. The time of increase is more uncertain, but apparently is nearly the same as that of decrease. The period of this Algol star, 31.4 days, is more than three times that of any other as yet discovered, and the duration of minimum, 2 days, is double that of S Cancri, the next in length." The predicted times of the next minima are Sept. 1, $2^h\ 44^m$ and Oct. 2, $10^h\ 2^m$, 1902. The star is BD + 43°4101 its place for 1900 being: R. A. $21^h\ 55^m.2$; Decl. + 43° 52′.



No. 11.1902 Lyræ was discovered by Mr. A. Stanley Williams, upon photographs taken at Hove, Eng., with a 4.4-inch portrait lens. It is apparently about 11^m at brightest and goes below 12^m at minimum. Its position for 1855 is R. A., $19^h\ 07^m\ 37^s.4$; Decl. + 14° 03′.7, lying about 4′ north of the seventh magnitude star BD + 40°.3624. The period is perhaps very near one year, though one of half that duration is not precluded. The next maximum will probably occur in August next.

No. 12.1902 Pegasi was found in the same field of view with Y Pegasi by Profeseor K. Graff of the Urania Observatory, Berlin. The accompanying chart shows the positions of the two variables relative to neighboring stars. The star just north of Y is BD 13°.4865 and that near the new variable is BD 13°4868. The magnitudes of these stars given in the BD are 9.5 and 9.3 respectively but Professor Graff estimates them at 9.0 and 9.9. He gives the following estimates of the new variable:

1902, April 24, $8^m.7$; April 26, $8^m.7$; May 9, $8^m.9$; May 14, $9^m.0$-$9^m.1$; May 19, $9^m.1$; May 28, $9^m.4$.

The following table gives the approximate places and magnitudes of the stars upon the chart:

No.	Star.	Mag.	R. A. 1855.			Decl. 1855.	
		m	h	m	s	°	′
1	BD + 13°.4863	9.9	22	04	13	+ 13	49
2	——	10.1	22	04	23	+ 13	59
3	Y Pegasi	var.	22	04	36	+ 13	38
4	——	10.1	22	04	38	+ 13	51
5	BD + 13°.4865	9.0	22	04	40	+ 13	43
6	BD + 13°.4868	9.9	22	05	09	+ 13	51
7	——	11	22	05	12	+ 13	58
8	12.1902 Peg.	var.	22	05	13	+ 13	50
9	——	10.5	22	05	43	+ 13	52
10	BD + 13°.4870	9.9	22	05	52	+ 13	38

Maxima of U Pegasi.

Period $4^h\ 29^m.8$. The minimum occurs $2^h\ 15^m$ after the maximum.

	h		h		h		h
Sept. 5	4	Sept. 11	4	Sept. 17	4	Sept. 24	2
6	2	12	2	18	2	25	5
7	5	13	5	19	5	26	4
8	4	14	4	20	4	27	2
9	2	15	2	21	2	28	5
10	5	16	5	22	5	29	4
				23	4	30	2

Y Lyræ.—Mr. P. S. Yendell has kindly drawn my attention to the fact that the light curve of Y Lyræ is similar to that of 7483 T Vulpeculæ as published by him and Mr. Sawyer a dozen or so of years ago, so that I am not the first to have detected the "cluster type" of variation in isolated stars. I suppose strictly speaking that this peculiar type should be called the "T Vulpeculæ" type instead of the "Cluster" type, but in this case there would be reasons for preferring the latter designation.

A. STANLEY WILLIAMS.

GENERAL NOTES.

Vacation time is past and serious work, a plenty of it, is in hand and pressing for attention. We hope to widen the influence of this publication in the near future, if our plans carry favorably.

Three more issues will complete the tenth volume of POPULAR ASTRONOMY. Never more than now has it been apparent to the management of this publication that there is a field of usefulness for it, and a widening prospect for advantageous growth.

Professor W. S. Burnham of the Yerkes Observatory, Williams Bay, Wis., has given up, for a second time, a very lucrative business pursuit, at his home in Chicago, that he may give his whole time and energy to practical work in astronomy. His great love for, and tireless devotion to, astronomy for the large part of his life makes this a very natural thing to do. Double stars will receive lively attention from him from this time on.

New Superintendent of the Naval Observatory.—By the Washington papers it appears that Captain Colby M. Chester, U. S. N., has been appointed Superintendent of the United States Naval Observatory, Washington, D. C., in place of Captain C. H. Davis, recently detached from the Observatory and given duty at sea. We know nothing of Captain Chester's qualifications for the important position to which he has been called, but must presume they are sufficient in the judgment of the appointing power, or he would not have been chosen. From recent Washington and New York papers, it is evident that things are being shaken up to the very bottom. Some excellent men who have heretofore enjoyed an enviable reputation as high-minded, intelligent and scholarly men, have become mixed up in this Naval Observatory quarrel in such a way as to besmirch their good names with (probably) undeserved and even shameless ridicule. The duty of the hour is to find out, at any cost, who and where it is that this rôle of anarchism is being played. If the source of it can be known there is power enough, near at hand, to put an everlasting end to it such as it deserves.

Measurement of the Eros Photographs at Northfield and Minneapolis.—The Directors of the Benjamin Apthorp Gould Fund have made a grant of $300 to Goodsell Observatory for the measurement of the Eros parallax photographs. By sharing the grant with the University Observatory at Minneapolis the loan of the Repsold measuring machine belonging to the latter institution has been secured and during the summer Dr. DeLisle Stewart and Professor Wilson have measured 66 of the plates which were secured from Sept. 26, 1900 to Feb. 4, 1901. Only a few preliminary reductions have been made. Six plates taken during the week Nov. 7-14, 1900 have been measured a second time, using a special list of reference stars selected by Mr. Arthur M. Hinks of the Cambridge Observatory, England.

For all the plates the reference stars were chosen from the list given in *Circulaire Nos. 8 and 9, Conférence Astrophotographique International.* From 6 to 12 reference stars were found within the area of good definition on all the plates.

During the coming months Dr. Stewart will assist Professor Leavenworth in measuring the Eros plates taken at Minneapolis.

Reduction of Mean to Sidereal Time.—In *A. N.* 3803 Mr. G. Lewitzky of the Dorpat Observatory gives an ingenious method of reducing an interval of mean time to the corresponding interval of sidereal time, and the reverse, which differs from any that we have seen. He uses the following little table constructed from the first four numerals and the two numbers 6.97 and 5.87:

a_0	ϵ	α_0
6.97	1	5.87
13.94	2	11.73
20.90	3	17.60
27.87	4	23.47

and the formulæ:

$$r = 10^s a - \left(\epsilon_0 + \frac{a - a_0}{7}\right)^s$$

$$\rho = 10^s \alpha - \left(\epsilon_0 + \frac{\alpha - \alpha_0}{6}(1 + 0.02)\right)^s$$

in which a and α are intervals of mean and sidereal time expressed in hours and decimals of an hour, a_0 and α_0 are the next smaller numbers in the table, and r and ρ are the reductions respectively from mean to sidereal and from sidereal to mean time. For a and $\alpha = 24$, these formulæ give $r = 236^s.557$ and $\rho = 235^s.910$

Auroral Phenomena or Zodiacal Light.—Referring to the June and July numbers of POPULAR ASTRONOMY and the criticism therein with reference to a portion of my paper on "Auroral Phenomena" published in the May POPULAR ASTRONOMY by your esteemed contributor, Mr. Arthur Harvey, F. R. S. C., of Toronto, who takes exception to my explanation of the curious light seen in England on March 4th, 1896. I will state that I am not inclined to accept his conclusion that the light in question was an enhanced manifestation of the zodiacal light, for the following reasons:

1st.—The streak of light was narrow, and its edges too well defined to confuse it with the cone-shaped form of the zodiacal light. In *Monthly Notices* for March 1896 Professor H. H. Turner in describing it says: "Its width was about 1°, and length 12°, its edges comparatively well defined and did not present the gradual fading off usually seen in the zodiacal light."

2d—Its rather rapid diminution in brightness and disappearance was more characteristic of the aurora than the zodiacal light. Mr. W. Lyon Browne writes [*Knowledge*, April, 1896], "It remained very bright for 3 minutes, when it gradually faded away, and in 10 minutes no trace was to be seen."

3rd—Motion was noticed by some observers; Mr. T. Law Webb [*Knowledge*, May, 1896] states that "he was not quite certain that it moved slightly towards the south, but was quite sure that at 9 o'clock its northern border towards the apex was nearly touching two bright stars near together and below the Pleiades, but that about 10 minutes later it was two or three times its own diameter to the south of them," also Mr. Goatcher [*M. N.*, March, 1896] noticed "the ray as of a yellow color and widening as altitude increased, it grew fainter and was evidently shifting southwards."

4th—Aurorae were quite prevalent throughout the British Isles, the United States and Canada on the night in question, and many observers describe the phenomenon as auroral.

Professor H. H. Turner [*M. N.*, March 1896] said that "after disappearance of the streak it was not again noticed, although auroral light and streamers were seen in the north; it is quite possible that the light seen in the west was an auroral display." Mr. Monckton [*M. N.*, March, 1896] writes that "there were on the sides smaller rays of light emanating as it were from the central luminous body." Mr. H. F. Newall, [*M. N.*, March 1896] regarded the light as auroral; also Mr. W. H. S. Monck cites a number of instances of very similar appearances and says regarding the light, "possibly it is more akin to the Aurora Borealis than to comets, meteors or the zodiacal light." [*Knowledge*, May, 1896].

The late Miss E. Brown cited a similar beam of light the year previous in nearly the same position, when aurora was visible in Scotland and the north of England. [*Knowledge*, May 1896.]

In commenting on the various descriptions given by the observers in *Knowledge*, for May, 1896, the editor, Mr. E. Walter Maunder, says of the object, "observations which have come more recently to hand show conclusively that the remarkable light seen on March 5th was auroral in character; there was an unmistakable aurora seen later in the evening, and some observers were able to follow out clearly the connection between the two."

5th—If the phenomenon was the zodiacal light, many similar cases would have been observed and recorded; true, numerous streaks both in the western and eastern heavens have been noted, but in all such cases aurora was either synchronal at the same locality or existed over wide areas and manifested its presence by streaks, beams or bright patches of light in the sky. Many such instances have been reported by observers of the weather bureau, and in the November 1901 number of the U. S. Monthly Weather Review an account is given of a peculiar streak in the western heavens which was visible November 28, 1901 at La Porte and Huntington, Indiana. Professor Cleveland Abbe commenting on this streak said, "The Aurora Borealis appears in every form, from the most magnificent display to the most insignificant patches of light that appear for a few moments and fade away forever, the above phenomena may well have been of the latter auroral character."

Unfortunately the position of the "curious light" of March 4, 1896 was nearly coincident with the axis of the zodiacal cone, and hence gave rise to uncertainty as to its true character.

DAVID E. HADDEN.

ALTA, Iowa, June 21, 1902.

New Factory of Lohmann Brothers.—We notice that Lohmann Brothers, of Greenville, Ohio, makers of refracting and reflecting telescopes, have recently completed their new factory, which with its three stories and basement has about 6500 square feet of floor space. The building is of brick and stone, special attention being given to the optical department in order to get the very best conditions for carrying on that branch of the work, irrespective of outdoor conditions. Underground apartments for storing valuable glasses, testing them, etc., are provided. We congratulate Lohmann Brothers upon their satisfactory work shop.

New Observatory for Amherst.—Professor D. P. Todd sends us the following clipping from the Springfield "Republican" of June 26, 1902: "The announcement that Amherst is at last to have a new Observatory which will in some degree be proportionate to the needs and the reputation of her department of astronomy, is one that has long been hoped for by the alumni. Although a fitting home for the department has been a cherished hope of Professor Todd's for the last 20 years, it was only two years ago that the movement which has culminated so successfully was inaugurated by the gift of $25,000 by a friend of the college, on condition that a like sum be raised within the year. At the expiration of the time set the amount was not complete, and was made up by pledges of certain individuals, while the whole matter was placed in the hands of a committee of the trustees of which George A. Plimpton, '76, was made chairman. The amount has now been raised, and the project is assured. The material used for building will be stone and brick. For the present the central dome and the left, or eastern wing, will be built, but perhaps before the building is completed, Professor Todd hopes to secure funds to fill out the plan and erect the western wing. The large central dome will be 33 feet in diameter and contain the new telescope, which will be the largest in New England, the diameter of the objective glass being 18 inches, and the length of the tube 14 feet. Each of the smaller domes will be 17 feet in diameter, the size of the present dome on the "octagon," and in one of these will be placed the old telescope. There are to be mounts of two transit instruments, one for the use of students and the other, a larger one, for the professor's use. The small dome and telescope, as well, will be devoted to student purposes and used by them for making independent observations. A fine clock room, with double walls and independent piers of granite for the chronometers will be a feature of the new Observatory. In the other wing will be the Observatory library, which, thanks to Professor Todd's efforts, already contains nearly 2000 volumes, many of them very valuable.

The department will not have to buy much new apparatus, as it already possesses some $10,000 worth of fine instruments, mounted and unmounted. The old telescope, with its 7¼-inch objective glass, is still an excellent instrument. The glass, one of the earliest and best turned out by Alvan Clark & Sons, is very clear, and when accompanied by modern improvements will still prove of great value. It was ground in 1853. A 12-inch reflecting telescope, which will be mounted in conjunction with the big tube in the central dome, was presented in 1891 by Rev. Dr. A. J. Lyman, of Brooklyn, is as yet unmounted. The same is true of a 6½-inch transit instrument which was obtained by Professor Todd some 17 years ago. A spectroscope was secured by the trustees in 1892, a chronograph in 1892, and last year a new and improved chronometer by Bond was purchased. The department is well supplied with apparatus for class-room work, including a skeleton sphere, presented by the sons of Thomas H. McGraw

of Poughkeepsie, N. Y., and a stereopticon, presented by the New York alumni.

The glass for the large telescope was obtained by Professor Todd several years ago, by very good fortune. The disk was by Feil of Paris for the exposition in 1889, and is said by experts to be the finest glass of its size that has ever come into this country. It will be ground by Alvan Clark & Sons, and the grinding will occupy 18 months. The 12-inch reflector which will be mounted on the same stand will prove of great value in taking photographs of stars and of eclipses. As regards the mechanical arrangements of the new Observatory Professor Todd a year or two ago spent several weeks in studying appliances and mechanism of continental observatories, and will embody the result of his investigations, together with numerous inventions of his own.

The building will in all probability be placed on the high ground adjoining Professor Todd's residence, but two other sites have been offered as gifts, and it is just possible that the Observatory may be erected on one of these. The site first mentioned is an admirable one in many respects. Although the Boston and Maine railroad runs within 200 yards of the hill, a series of careful experiments by Professor Todd with a mercury basin has failed to reveal the slightest tremor. The hill is bare of large trees, and is almost as large as College hill. The building will face to the north. Much more practical work will be done by the students than at present, as the facilities for observations will be greatly increased. Ground for the new building will not be broken until the fall.

Queries.—1. Of what is the zodiacal light composed? Ans.—It is supposed that the zodiacal light is due to the reflection of sunlight from myriads of small particles of matter in the space between the Earth and the Sun. This matter circulates about the Sun under the influence of the attraction of the latter, just as the planets do. It is most abundant near the Sun but is scattered throughout an immense discus-like portion of space extending out nearly to, if not beyond, the Earth. The plane of the Earth's orbit, or the ecliptic, very nearly if not exactly bisects the space which is occupied by the zodiacal light matter.

2. What causes the stars to seem to twinkle? Ans.—This is mainly due to the fact the air through which the starlight comes to us is full of streaks of unequal density which are carried by the wind. Light in passing from one medium to another of unequal density is refracted or turned aside from its straight course. The effect upon a star's light passing through our atmosphere is in some places to concentrate the rays that come side by side and in others to separate them, so that the stars may at alternate moments appear brighter and fainter. The effect upon different rays reaching the eye at the same moment by slightly different routes may be such as to cause them to interfere, *i. e.*, destroy each other's effect upon the eye, so the star may momentarily disappear. The interference may be only partial, destroying some colors and allowing others to show conspicuously so that the star flashes red or green or blue.

3. What is the very brilliant star in the east of Sagittarius that appeared early in July? Ans.—This is the planet Jupiter. The next most brilliant object in that part of the sky, about 20° to the west of Jupiter is the planet Saturn.

Clouds and Weather Signs is the title of a pamphlet received by Commander D. Wilson-Barker, and printed at the *Knowledge* Office, 326 High Holborn, W. C. London, England. It is illustrated with a large number of fine cuts from original photographs.

The object of this short study of clouds (which is reproduced from *Knowledge*) is to call attention to a much neglected theme that ought to receive more attention because it is "a fascinating field of study." A look at the plates of this little book shows what a helpful guide it is in the hands of an interested reader. The first plate shows the forms of the Squall-cumulus clouds, the figure is the shower cumulus form, and plate II is the common summer cumulus and next the pillar cumulus.

After this the stratus clouds are shown and described and the mackeral sky. Then follows illustrations of the cirus clouds and the high stratus mackeral sky. It has been rightly said: "No branch of Knowledge offers greater facility and ease of acquisition. Each cloud has its history fraught with meaning; its open secret is writ on its face, and may be read by anyone who will give himself a little trouble, nor need he go deeply into the study in order to make observations interesting to himself, and perhaps of great use in the furthering and perfecting of weather lore, to which, lndeed, clouds may be said to furnish the key."

Finally the author gives a brief description of the halo and illustrations of the same. This pamphlet of 31 pages has 17 fine illustrations, and can be procured for one English shilling net, post free.

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